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THESIS

AN EXAMINATION OF THE CONCEPTUAL BASIS OF A
TACTICAL, LOGISTICAL, AND AIR SIMULATION
(ATLAS).

by

Man Kwon/Nam

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March 1980

Thesis Advisor: J. G. Taylor

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The increased need of evaluation of recent worldwide operational contingencies leads various military-staff and defense-planning agencies to use an existing theater-level-combat simulation for such evaluation work. In this context, the ATLAS (A Tactical, Logistical, and Air Simulation) model is a candidate. This model has been widely used in the United States. However, the ATLAS model has some

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An Examination of the Conceptual Basis of a
Tactical, Logistical, and Air Simulation (ATLAS)

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The increased need of evaluation of recent worldwide operational contingencies leads various military-staff and defense-planning agencies to use an existing theater-level-combat simulation for such evaluation work. In this context, the ATLAS (A Tactical, Logistical, and Air Simulation) model is a candidate. This model has been widely used in the United States. However, the ATLAS model has some particularly severe potential limitations due to its aggregation methodology. Furthermore, its current documentation is quite poor and non-comprehensive to the general user. This thesis presents a detailed description of the conceptual basis of ATLAS for providing a better understanding of the model to the general potential users. The thesis identifies the model implications, analyzes the model logic and functional areas, discusses the model characteristics, and finally gives some suggestions for the use of ATLAS.

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I. INTRODUCTION

ATLAS (A Tactical, Logistical, and Air Simulation) is a highly aggregated, deterministic, and fully computerized combat model of non-nuclear theater-level warfare between two opposing combat forces. ATLAS, which is currently more widely used in the United States than any other operational theater-level combat models, was developed by Research Analysis Corporation (RAC) for the Office of the Assistant Secretary of Defense for System Analysis [OASD(SA)] in 1967. In 1962 RAC developed a theater-level combat model called the "Quick Game." By early 1967 the manual quick game had been expanded and converted to an operational computer simulation. The "Computerized Quick Game"[1] has been later retitled "ATLAS," an acronym for "A Tactical, Logistical, and Air Simulation."

The principal design objective for ATLAS was to assist the planner or analyst by simulating conventional theater-level combat operations over an extended period, and to examine the overall trends, effects, and interactions of ground, air, and logistic forces in conventional theater-level warfare. It is basically a planner's war game,

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[1] Research Analysis Corporation, "Computerized Quick Game: A Theater-Level Combat Simulation," Vol I, "Models," RAC-TP-266, Nov 67.

providing the tool for examining theater-level force interactions so that the planner/analyst may examine and evaluate theater-level contingency planning, force effectiveness, and force requirements. The fundamental assessment basis of ATLAS is the aggregated firepower score, force ratio and FEBA movement rate algorithm. The model is relatively simple because it is highly stylized and is also very efficient in terms of resources required. Furthermore, it should be emphasized that ATLAS was designed as a "quick game" and not as a detailed (and slow-running) model of theater-level operations.

During the past years ATLAS has been widely accepted by military planners,due particularly to (a) the increased need of evaluation of recent worldwide operational contingencies, and (b) the relative adequacy of ATLAS as a suitable theater-level combat simulation to meet such need. It was estimated that as of August 1977 the approximate frequency of use of ATLAS was 600 times per year, just comparing with 50 times per year as of June 1975 [17], [18]. ATLAS has been most extensively used both within the Army and at other agencies: the Supreme Headquarters, Allied Powers Europe (SHAPE) Technical Center; the Studies, Analysis, and Gaming Agency, Organization of the Joint Chiefs of Staff (SAGA,OJCS); the U.S. Army Concepts Analysis Agency (CAA); RAC's FOREWON System.[2]

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[2]Force and Weapons Analysis. An Army force planning system comprised of several models (ATLAS, FASTVALS, FCA,OFD, PFD-LP, and PED-SAM).

The extensive use of ATLAS over the last several years
for evaluating contingency plans has led to many modifi-
cations to the original version of ATLAS. RAC has published
two volumes[3] as the documentation of ATLAS, restricted to only
a general description of the logic and required input data of
the model. Actually, those documentations are shown to be
somewhat brief and simplistic as the guidance for the model
user, even though at the highly aggregated level the documen-
tation is necessarily general. At this point, a critical
question arises: Are those documentations adequate as a
user's guide? Model adequacy is generally determined by the
ability of other than originators to understand and use the
model. In fact, on the contrary to the wide potential use
of the ATLAS model its current documentation seems poor. In
other words, from the user's viewpoint it has been and is
still recognized that there is a lack of comprehensive
documentation to enable an analyst to understand the conceptual
basis of what is being done within the model.

A recent critique for the status and adequacy of current
documentations including one of ATLAS has been given by

---

[3]See, for example, Robert H. Cole and Edward P. Kerlin,
"Computerized Quick Game: A theater-Level Combat Simulation,"
Vol I, "Models," Research Analysis Corporation, Nov 1967.

Szymczak in 1979 [16]. The possibility of problems
attributable to inadequate model documentation has been
pointed out by him.

> ...the practice has been to use someone else's model
> without throughly understanding its implications and
> limitations due to the use of inadequate documentation.
> At times this has resulted in erroneous conclusions
> being drawn and decisions being based on these con-
> clusions. Subsequently, the errors are surfaced with a
> loss not only in dollars expended in pursuit of un-
> desirable projects but further loss of credibility for
> the model...

Likewise, the use of ATLAS has some severe problems
associated with it when the model is used like a "black box."
Actually, although there has been a noticable improvement of
the model, the author still feels that the level of document-
ation of ATLAS is not sufficient to insure the easy and
proper use of the model without supplementing the current
documentation. To emphasize, without deep understanding of
the conceptual basis of the model through the adequate
documentation, the analyst is apt to make erroneous con-
clusions regarding the processes occurring within the model.

This thesis is intended as not a modification or
supplement but an examination of the conceptual basis of
ATLAS. The objective of this effort is to present the com-
prehensive description of ATLAS through: (a) identification
of the model implications; (b) examination of the model logic
and functions; and (c) discussion of the model characteristics,
and thus to provide the potential users an understanding of
the model. The thesis begins with Chapter II giving a
general description of ATLAS including theater structure,

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overall model logic, and game operations. This is followed
by an examination of the logical processes of each principal
model of ATLAS in Chapter III. Chapter IV describes an
identification of major assumptions of the model. A detailed
analysis of functional analysis of functional areas of the
model is given in Chapter V. Chapter VI discusses the
overall characteristics of ATLAS covering limitations,
strengths, applications, improvements, computer-related
aspects, and documentation of the model. The final chapter
gives some concluding remarks and suggestions for the use
of ATLAS. This paper does not deal with any sensitivity
analysis or does not consider program-operating instructions
and preparation of required input data. The main source for
this thesis were references [1], [2]. The reader is, if
necessary, urged to consult those references in conjunction
with this thesis.

II. GENERAL DESCRIPTION OF ATLAS

A. GENERAL

ATLAS is fully automated theater-level simulation and was designed generally to determine combat force requirements and capabilities in conventional theater warfare. Its major advantage is the "speed" with which it can be run. Once the theater forces and environment have been analyzed and the input data prepared, any of the planning assumptions and alternatives can be examined with the expenditure of very few minutes of computer time. Types of change that can be evaluated are variations in troop availability, presence or absence of LOCs (lines of communication) and hence supply availability, varying levels of tactical air support, and delays imposed by certain barriers techniques.

ATLAS is based on a simple algorithm for using historical data about division movement, casualties, and ammunition expenditures. In addition, ATLAS largely depends on aggregated "firepower scores" to determine engagement type and outcome. The principal assessment is the daily determination of the change in the location of the Forward Edge of the Battle Area (FEBA) in each sector. The rate of advance of the attacker for each sector is determined as a function of: the posture of the defender; the condition of the terrain; the mobility of the attacker; the attacker-to-defender force ratio. A detailed examination of firepower scores, casualties,

rates of advance, and other functional areas of the model is given in Chapter V.

The pattern of combat in ATLAS is quite rigidly specified by the game rules. Since ATLAS is deterministic, one set of input values always yields the same result. This deterministic characteristic is a distinct advantage in military planning. However, it is felt that because of many of the limitations even for its speed of operation and simplicity, ATLAS cannot be used for battles of more than a week's duration, without a careful analysis of weekly result and a revision of inputs when necessary. Under no circumstances should the output of ATLAS, for an extended campaign, be accepted without a thorough examination of the periodic decisions simulated during the run.

B. THEATER STRUCTURE

To apply ATLAS to a given combat environment, the simulation regards the tactical battlefield as being divided into non-interacting battle areas called "sectors", shown in Figure 2-1. The sectors extend from rear areas of one force through the theater to the FEBA, and into the rear areas of the opposing force. Normally the smallest discrete combat unit deployed in one sector is a combat division (a maximum of one corps force). Each sector is composed of a sequence of "segments" each of which may be considered to yield a constant trafficability to military units. Adjacent segments differ from one another by some characteristic of military significance that affects overall trafficability,
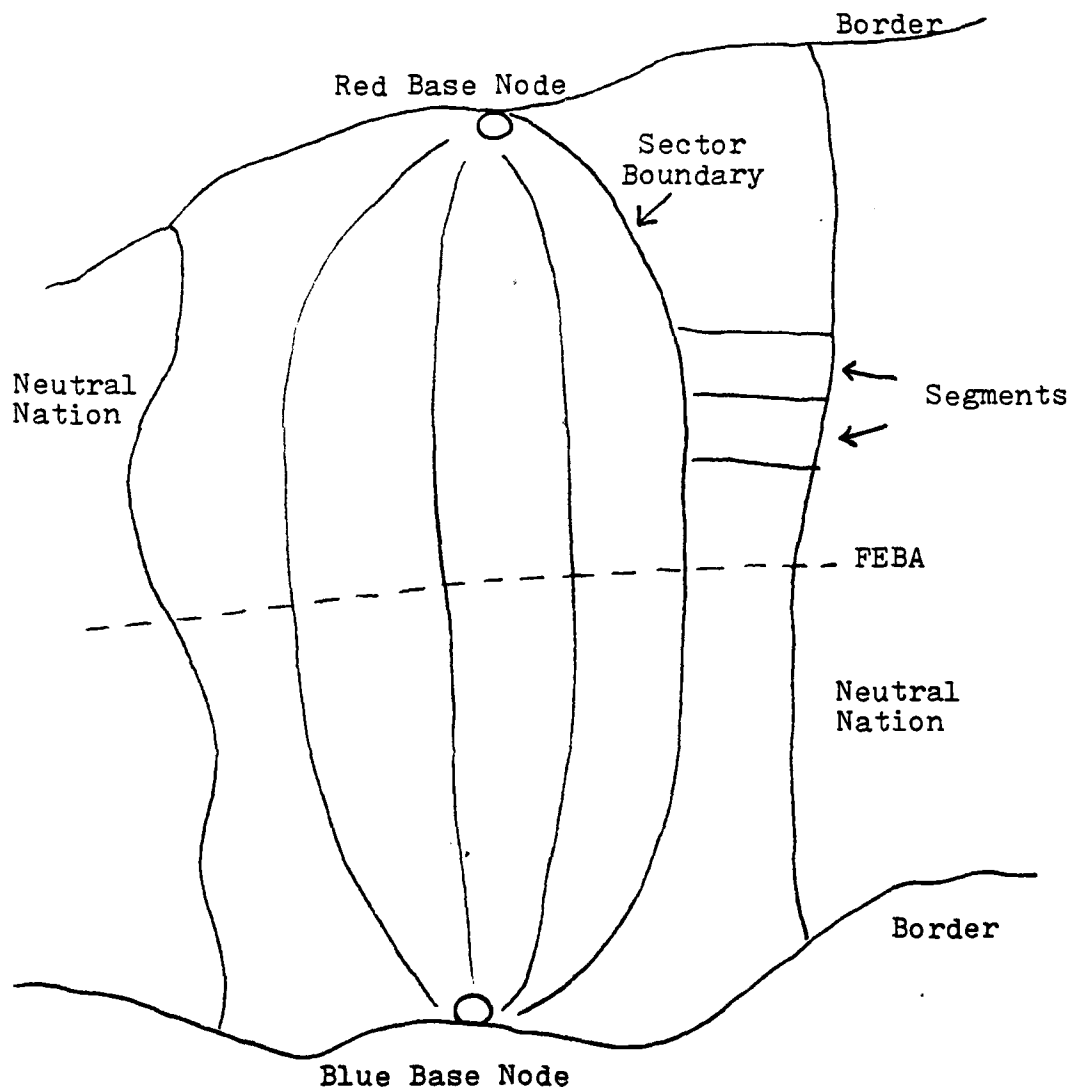
Fig. 2-1 Schematic Representation of Sectors and Segments

Red Base Node

FEBA

Sector Boundary

O   Supply Nodes

- - -   LOC

Blue Base Node
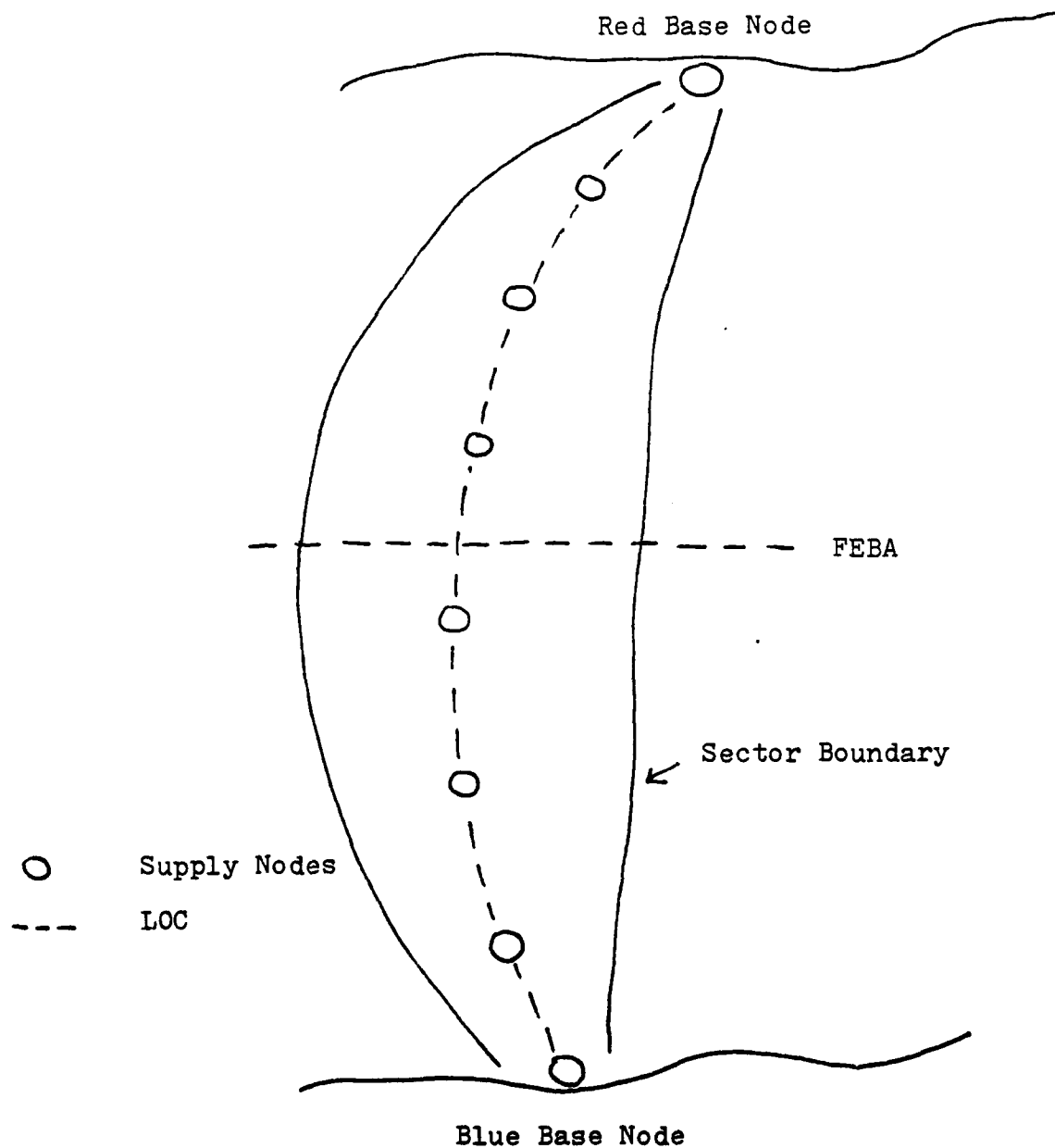
Fig. 2-2 Schematic Representation of the Sector Node System

such as terrain changes, man-made barriers, or prepared defense positions.

Within each sector the terrain is described in terms of segments and ATLAS identifies three types of terrain as follows:

(a) Type A. Open, flat, or generally rolling terrain with a minimum of timber.

(b) Type B. Marginal terrain for armored operations.

(c) Type C. Mountainous, jungle, or thickly wooded terrain.

Three types of terrain and man-made barriers affect military movement, so six types of terrain-barrier combinations are simulated in the model.

Each battle sector also has a logistics system as shown in Figure 2-2. In each sector the network of ground Lines of Communication (LOCs) is represented by a series of single LOCs connecting nodes approximately 1 day's overland journey apart. This spacing is necessary for the model to operate on a daily basis. The location of each node is related to ports, airfields, or rail and road junctions within each sector. Nodes are also linked by air LOCS if air bases are available. A node may have associated with it either a SAM site, a tactical air base, or both. As far as the operation of the logistics model is concerned, these entities are considered as part of the total demand on a node for resupply purposes.
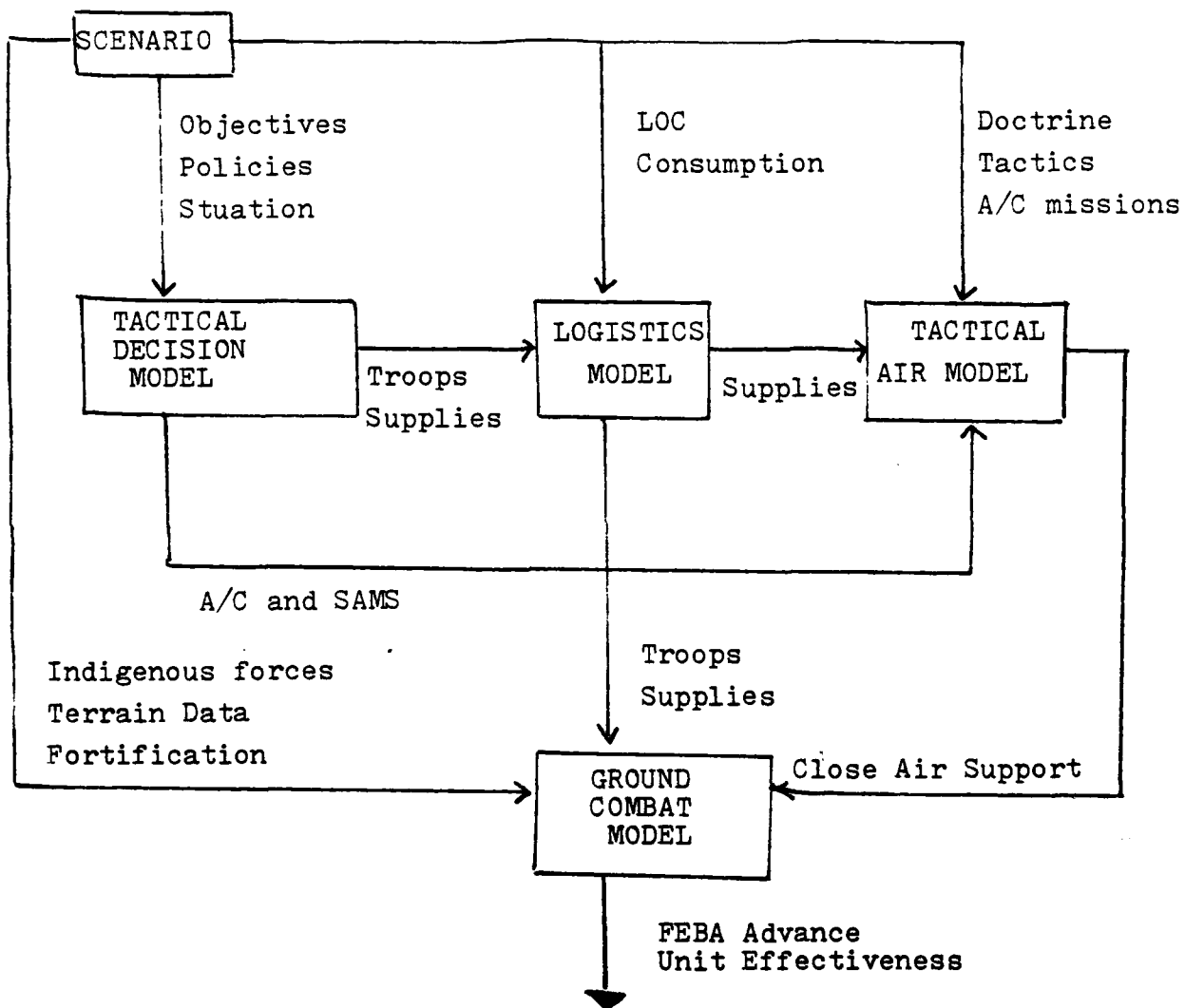
Fig. 2-3. Overall Model Logic of ATLAS

C. OVERALL MODEL LOGIC

ATLAS consists primarily of four separate but interacting models: (a) the Ground-Combat Model, (b) the Logistics Model, (c) the Tactical-Air Model, (d) the Tactical-Decision Model. Figure 2-3 shows schematically the model interaction within the overall simulation, indicating some of the input to and output from each model. A game scenario that states the specific objectives, the constraining policies to be followed, and the combat forces available, essentially guides the simulation from the start. From this scenario and the developing tactical situation comes information which triggers the tactical-decision model into sending troops, supplies, and equipment to the other models. These models then interact in a tactical sense and thus develop the combat situation. The models referred to here are representations of objects or events in the real world that are idealized insofar as only selected properties of reality are represented, making them therefore less complicated than reality. All the models are deterministic in that the outcome is predictable with certainty and the element of chance is totally absent. Some of the models are mathematical in that properties of the things represented and their interactions are expressed symbolically by means of mathematical expressions.

The tactical-decision model, on the basis of the Red and Blue strategies, the schedule for the order of battle, and the existing military situation, allocates, by sector, the troops, supplies, and equipment needed for effective combat

action. This model, while simulating an air commander, assigns tactical aircraft to support each battle sector each day.

The logistics model simulates, for each sector, the flow of troops and supplies from the point of debarkation to the forward-echelon supply point. All existing air and ground LOCs are idealized into two LOC systems: one for fixed-wing aircraft and one combining ground and helicopter capability. Enemy interdiction of the LOCs and supply points can result in a degradation of the combat capability of the forces in action.

The tactical-air model simulates the effect of tactical aircraft in a combat situation together with the effect of weapons to destroy the aircraft. The presence of transport aircraft is implied in the logistics model in the form of tons per day of aircraft capability, but individual planes are not played. Five types of tactical air mission are simulated in the model as well as the effects of surface-to-surface missiles (SAMs) and air-defense-artillery (ADA) weapons. The five types of mission are: (a) SAM suppression, (b) air base interdiction, (c) air defense, (d) close air support (CAS), and (e) LOC and supply-point interdiction.

The ground-combat model determines changes in the location of the FEBA for each sector daily (every 24 hr). By determining the force ratio and the posture of the engaged troops, the rate of advance of attacker is determined. The force ratio, in terms of opposing combat-effectiveness values,

accounts for the presence of CAS aircraft, supporting artillery, the tactical posture of the troops, and the overall unit effectiveness. Ineffective units are removed from combat and withheld long enough for them to be restored to full combat effectiveness; they are then returned to combat. New units entering the theater are assigned to a particular sector by the tactical-decision model, travel through the theater LOC network within the logistics model, and are deployed for combat as new fighting units in the ground-combat model.

D. GAME OPERATIONS

The first task in creating a theater situation for game play is to thoroughly prepare the scenario including the purpose and scope of the proposed war game. Since a computer simulation rigidly adheres to the inputs and programmed rules of assessment it is essential that the inputs accurately reflect the situation envisioned in the scenario. A full understanding of the purpose of the game and the model logic will help the analyst to structure the theater so as to allow maximum flexibility.

Preparation of inputs is the next big task. From a theater point of view, the scope of the inputs requires consideration of most of the operational and technical parameters governing combat operations. The scenario will usually provide most of these operational data although not always in sufficient detail to meet the requirements of ATLAS.

The major operational data the analyst must consider are.
(a) the geographic limits of the planned theater of oper-
ations, (b) the opposing strategies, (c) orders of battle,
(d) organization for combat, (e) resources to be allocated
to each side for tactical-air and logistical support, and
(f) the time of the assumed D-day. In general, the overall
input data for ATLAS comprises four major categories:

(a) Environmental inputs which structure the theater;

(b) Ground force inputs of committed and scheduled
forces and their associated characteristics;

(c) Logistic inputs which establish supply requirements
and constraints;

(d) Air inputs which provide performance, vulnerability,
and other characteristic data on aircraft, airbases,
and SAM sites.

Approximately 100 data items are required for operation of
the model. However, the number of data values that are used
with the various data items can become quite sizable (approx-
imately 10,000 data values).

Model output is in a computer printout form somewhat
similar to the input data format. Output is tabulated on a
daily basis and reflects the current status of forces at a
given time. The Planner or analyst must incorporate model
results into his analysis of the theater scenario. Selective
detailed and summary output is available. Output may be
requested for specific days and for specific submodels or for
a comprehensive theater summary. Retrievals of selected

data items are also available using the ATLAS data conversion and retrieval programs.

Play of the game may be terminated when one of the following four events occurs: (a) a specific number of days has elapsed, (b) the enemy has forced his way through to the friendly ports of debarkation, (c) the defending forces have stabilized the FEBA in all battle sectors, or (d) the friendly forces have everywhere force the enemy back some objective line such as the border of the country being defended.

III. EXAMINATION OF LOGICAL PROCESSES OF ATLAS

A. TACTICAL-DECISION PROCESS

1. The Tactical-Decision Model

The tactical-decision model is needed to allow the simulation to proceed through an entire war without interruption. One application of the simulation is to assist in rapid deployment studies, where troops, supplies, and equipment will be scheduled to arrive at ports and airbases at various times during the war. Specifically this model is designed to determine the sectors to which newly arrived combat units might best be deployed, to determine the distribution of supplies and SAM units as they enter the theater, and to allocate tactical aircraft on a daily basis to each sector for both sides.

Figure 3-1 shows the general flow diagram of the logical process for the tactical-decision model. For control of daily allocation of combat aircraft, the model simulates an air-control authority (ACA) that determines the percentage of aircraft under its control, based on the tactical within the sector. The allocation schemes developed for assigning combat units and SAM units to sectors may be overridden by a sector assignment specified in the input data. An input of this type allows the tactical-decision routine to be bypassed only the entries specified.
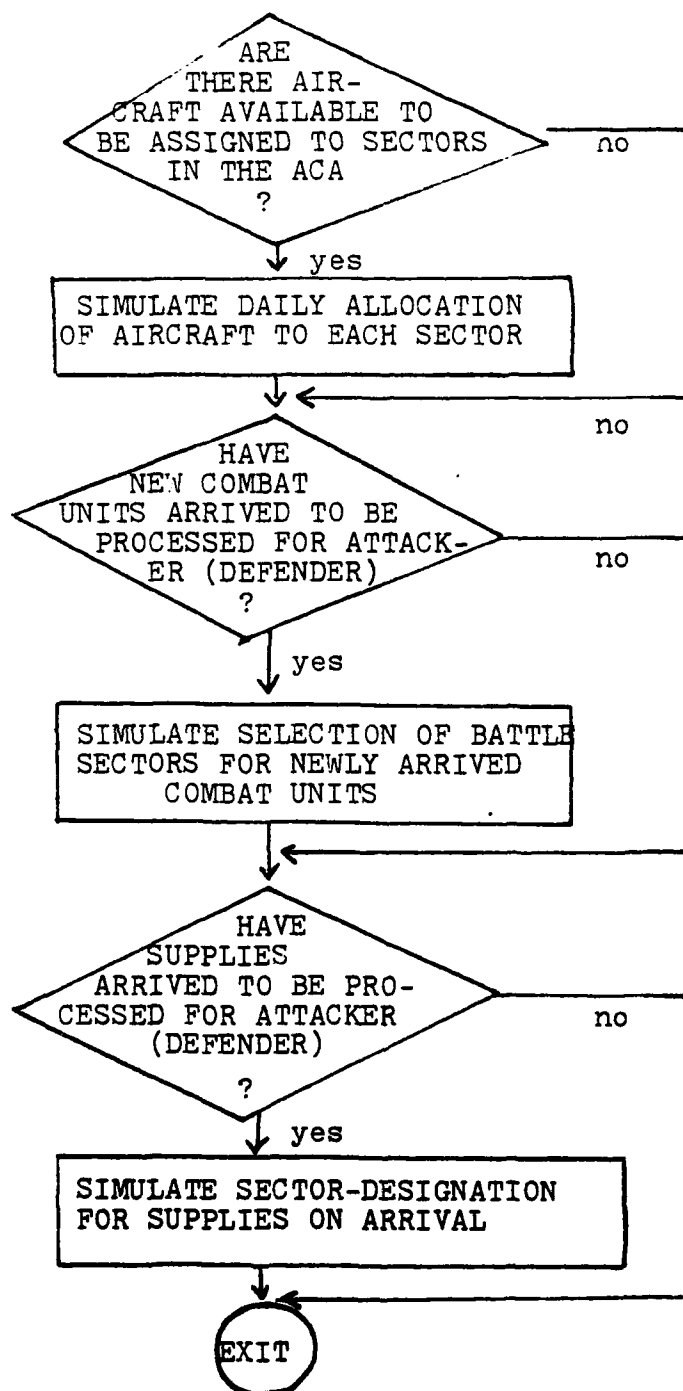
Fig. 3-1 Generalized Flow Diagram of the Tactical-Decision Model

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2. Allocation of Combat Aircraft

The allocation of combat aircraft to battle sectors
is a function of the tactical situation existing in the sector
and its logical process is shown in Figure 3-2. Three tactical
situations are possible: (a) Red forces advancing, (b) Red
forces retreating, and (c) forces stalemated. These situa-
tions are assumed to be assignment priorities 1, 2, 3 in
the order a, b, c for the Red forces and a, b, c for the
Blue forces. Thus, each day the aircraft are assigned to
the highest priority available. If the same situation exists
in more than one sector, aircraft assigned in proportion to
the index of combat effectiveness (ICE) of the opposing force
in the sector involved. Hence, any desired change in the
logic or priority assignment of aircraft may be made by
reordering the above situations.

When the defender's strategic phase line is penetrated,
the allocation scheme is applied differently. Once one or
more sectors is penetrated, all the defender's aircraft are
assigned in ratio to the ICE of the units making the pene-
tration. Once the advancing units are halted, the defender's
aircraft are assigned to sectors according to the usual
allocation scheme. When the phase line has been penetrated
in all sectors, an alternative phase line is brought into
being and the aircraft assignments follow as before.

3. Assignment of New Combat Unit

The selection of battle sectors to which newly
arrived combat units are assigned is based on the attacker's
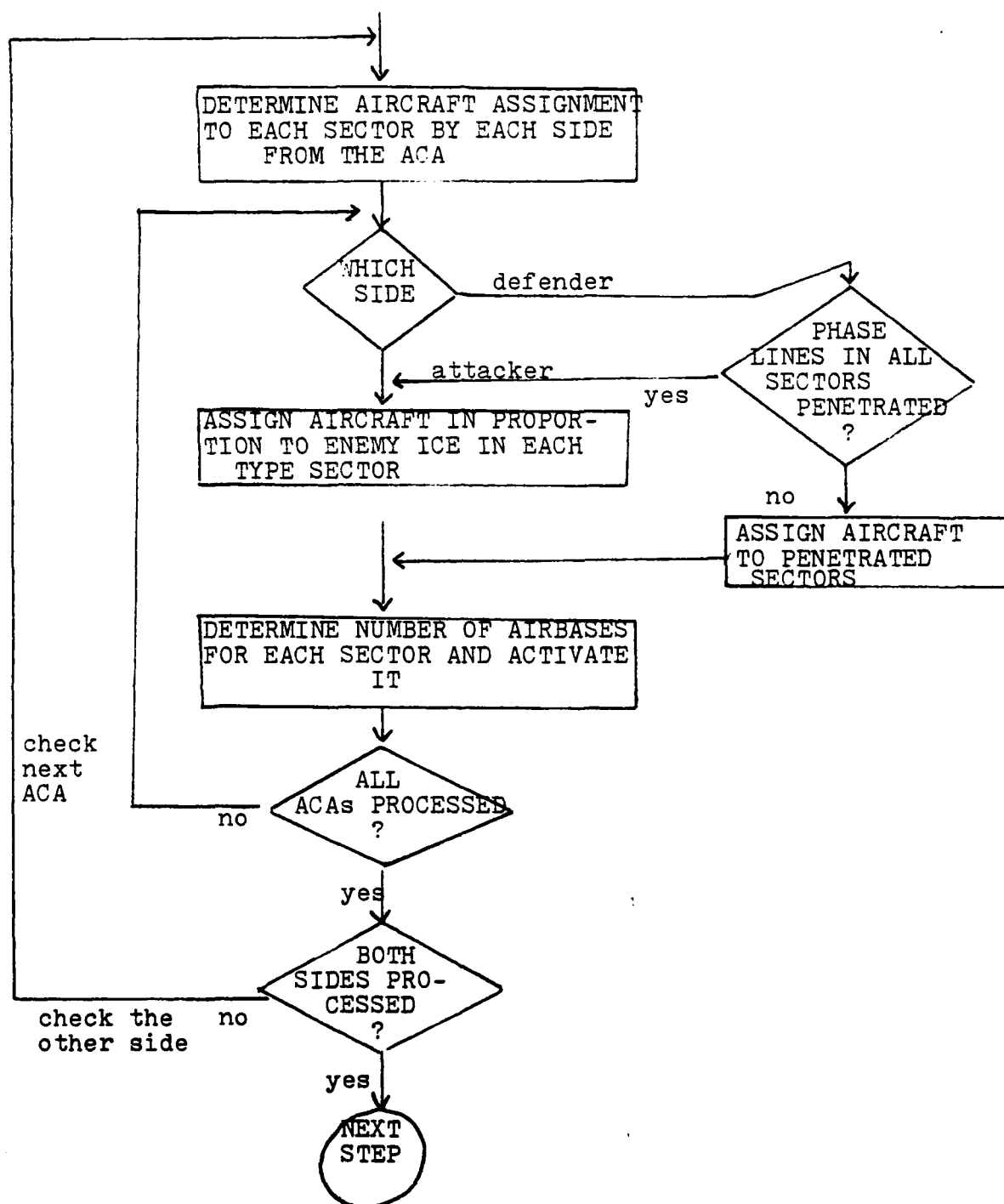
Fig. 3-2 Logical Process of Allocation of Combat Aircraft
to Sectors

rate of advance or cumulative distance advanced toward some strategic objective phase line and on the ability of the LOCs and logistic system to handle additional units. The basic philosophy being followed is that an attacker will attempt to advance to an objective as quickly as possible without losing ground already captured and the defender will strengthen areas in an attempt to halt the attacker's advance.

The logical process of the assignment of new units to battle sectors is shown in Figure 3-3. After viewing the type of combat actions in all battle sectors, the model determines in which sector the attacking force could reach some predesignated defense position in minimum time. This position may be a strategic phase line or the enemy's final objective itself. The sector thus selected receives the new units. If there is no movement on the front when this assessment is made, minimum distance becomes the criterion instead of minimum time.

Instances may well occur, however, where an additional unit assigned to a sector will overburden the logistics capability of the sector. Therefore, before the new unit is assigned to the sector, the ability of that sector to resupply existing combat units, to transport replacement items and supplies, and to move the new unit through the system is carefully evaluated. If the sector in its present condition is not able to handle the new units, other sectors are then evaluated as to their capability, always keeping the tactical need foremost in mind.

```
┌─────────────────────────────────┐
│ DETERMINE SECTOR WHERE ATTACK-  │
│ ER CAN REACH NEXT PHASE LINE    │
│ OR OBJECTIVE IN MIN. TIME       │
└─────────────────────────────────┘
```

CAN SECTOR SELECTED GET UNIT INTO COMBAT IN 2n DAYS? (n: # of nodes)

NEXT STEP

yes

no

HAVE ALL SECTORS TO THIS POINT OF DEBARKATION BEEN CHECKED?

yes

ASSIGN NEW UNIT TO SECTOR THAT IN-ITIALLY REPRESENTED MIN. TIME TO NEXT PHASE LINE OR OBJECTIVE

no

DETERMINE SECTOR WHERE ATTACKER CAN REACH NEXT PHASE LINE OR OBJECTIVE IN NEXT MIN. TIME

Fig. 3-3 Logical Process of Assignment of New Combat
          Units to Sectors

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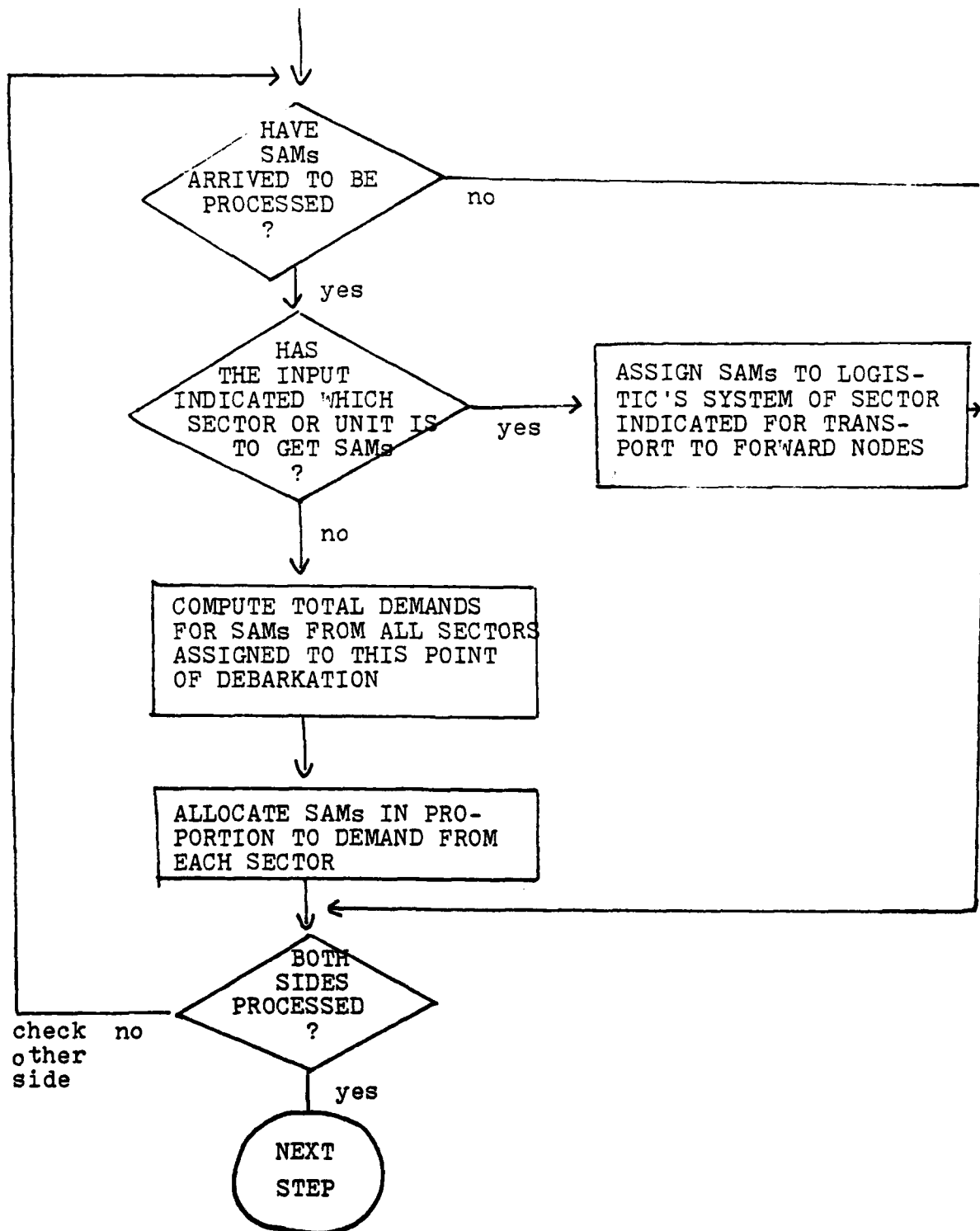
Fig. 3-4 Logical Process of Assignment of SAM Units to Sectors

4. Assignment of SAM Units

The assignment of SAM units to battle sectors, if not spelled out by the scenario, is determined by the tactical-decision model, following their planned arrival time into the theater. Figure 3-4 shows the logical process of the assignment of SAM units to battle sectors. SAM units, generally in battery-sized units, will be attached for resupply purposes to the most forward supply node of each sector first. The follow-on batteries of SAMs also will be assigned to this forward node until the degree of mutual support desired is achieved, at which time SAM batteries will be assigned to the next rearward node. This allows for defense in depth as called for by the deployment doctrine. It is possible, however, to override the tactical-decision model and, by appropriate input, designate the sector and node that will receive the SAM units as they arrive in the theater.

B. LOGISTICS

1. The Logistics Model

The logistics model in ATLAS simulates the resupply of deployed combat units, builds stockpiles at designated points in the theater, and simulates the flow of the troops and equipment through the theater LOCs, so that a realistic delay exists between units arriving in the theater and being deployed as combat active. In addition the logistics model becomes the prime vehicle for assessing the effects on combat of enemy interdiction of supplies.

```
┌─────────────────────────────────────────┐
│ UPDATE THE FORWARD SUPPLY NODE           │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│ ASSESS EFFECTS OF NODE INTERDICTION      │
│    AND NODE INTERNAL CONSUMPTION         │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│ CREATE RESUPPLY DEMAND OF COMBAT         │
│              UNITS                       │
└─────────────────────────────────────────┘
                    │
                    ▼  ◄─────────────────────────┐
┌─────────────────────────────────────────┐      │
│ SIMULATE MOVEMENT BY GROUND AND AIR      │      │
│ OF SUPPLIES TO ONE NODE FROM THE         │      │
│ NEXT                                     │      │
│ MEET ALL EXTERNAL DEMENT AND NODES       │      │
│ THEMSELVES                               │      │
└─────────────────────────────────────────┘      │
                    │                             │
                    ▼                             │
┌─────────────────────────────────────────┐      │
│ SIMULATE MOVEMENT BY REMAINING           │      │
│ GROUND CAPABILITIES, IF ANY, OF          │      │
│ NEW UNIT AND ASSESS STOCKPILE            │      │
│            REQUIREMENTS                   │      │
└─────────────────────────────────────────┘      │
                    │                             │
                    ▼                             │
                 ╱ALL ╲                           │
                ╱NODES IN╲                        │
               ◄ SECTOR   ►──── no ───────────────┘
                ╲EXAMINED ╱
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                  ( A )
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Fig. 3-5 Generalized Flow Diagram of the Logistics Model
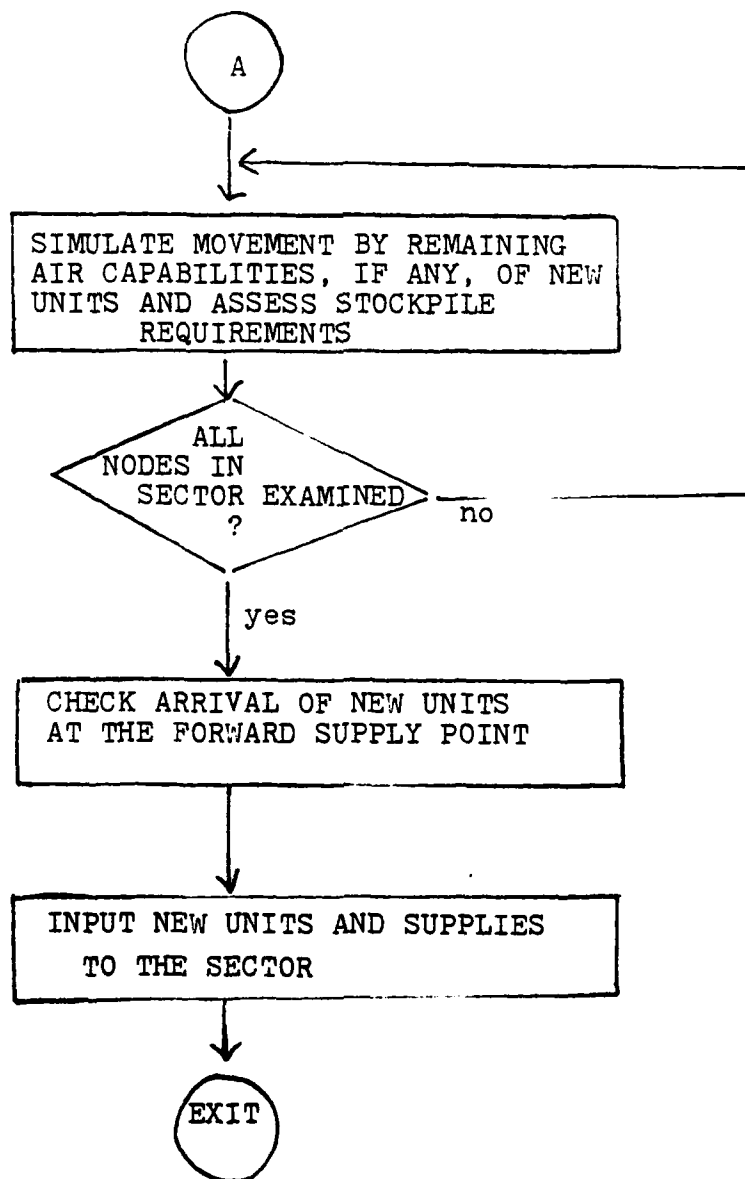
Fig. 3-5 cont.   Generalized Flow Diagram of Logistics
                 Model

The general flow diagram of the logical process for
the logistics model is shown in Figure 3-5. The logic that
simulates the flow of supplies is the same for each sector
and deals first with the forward node. A demand from the
ground combat units, which varies with the number and type
of the demanding unit as well as its combat posture, is
created and sent to the forward node. If this node cannot
meet the demand, the next most rearward node attempts to
meet it. If this node also fails, supplies may be forwarded
by air from a more rearward node if the capacity is available.
When the daily movement of supplies has been completed all
remaining ground airlift capabilities are used to move new
troops and equipment to the combat zone.

The logic of logistics model was designed so that
for stable combat conditions and adequate logistic support,
supplies should support flow smoothly into the forward supply
node and hence to the consuming units. However, if the move-
ment capacities are low, or the enemy interdiction effort is
heavy, the combat effectiveness of active units may be degraded
and the total number of combat missions that could be flown
from any one airbase may be restricted.

2. **Movement of Supplies and New Units**

In ATLAS, supplies are moved through the sector to
meet the demands from the ground-combat units, the SAM and
tactical-airbases in the sector, as well as responding to
the consumption of supplies by the nodes themselves. Any

```
                    │
    ┌───────────────┼──────────────────────┐    │
    │               │                       ▼
    │      ┌──────────────────────────────────┐
    │      │ CALCULATE FORWARD DEMAND AND     │
    │      │ ALLOCATE SUPPLIES TO SAM SITE    │
    │      │         AND AIRBASE              │
    │      └──────────────────────────────────┘
    │                       │
    │                       ▼
    │      ┌──────────────────────────────────┐
    │      │ DETERMINE SUPPLIED FORWARDED     │
    │      └──────────────────────────────────┘
    │                       │
    │                       ▼
    │                  ╱ IS ╲
    │                ╱ THIS NODE ╲          no        ┌───┐
    │              ◁ FORWARD SUPPLY ▷─────────────────▶│ B │
    │                ╲  NODE?   ╱                      └───┘
    │                  ╲     ╱
    │                     │
    │                     │ yes
    │                     ▼
    │      ┌──────────────────────────────────┐
    │      │ ALLOCATE SUPPLIES FORWARDED TO   │
    │      │ GROUND UNITS AND CALCULATE NEW   │
    │      │     DEMAND ON THE NODE           │
    │      └──────────────────────────────────┘
 check the                 │
 next                      │
 rearward   ┌───┐          │
 node       │ A │◀─────────┘
            └───┘
```
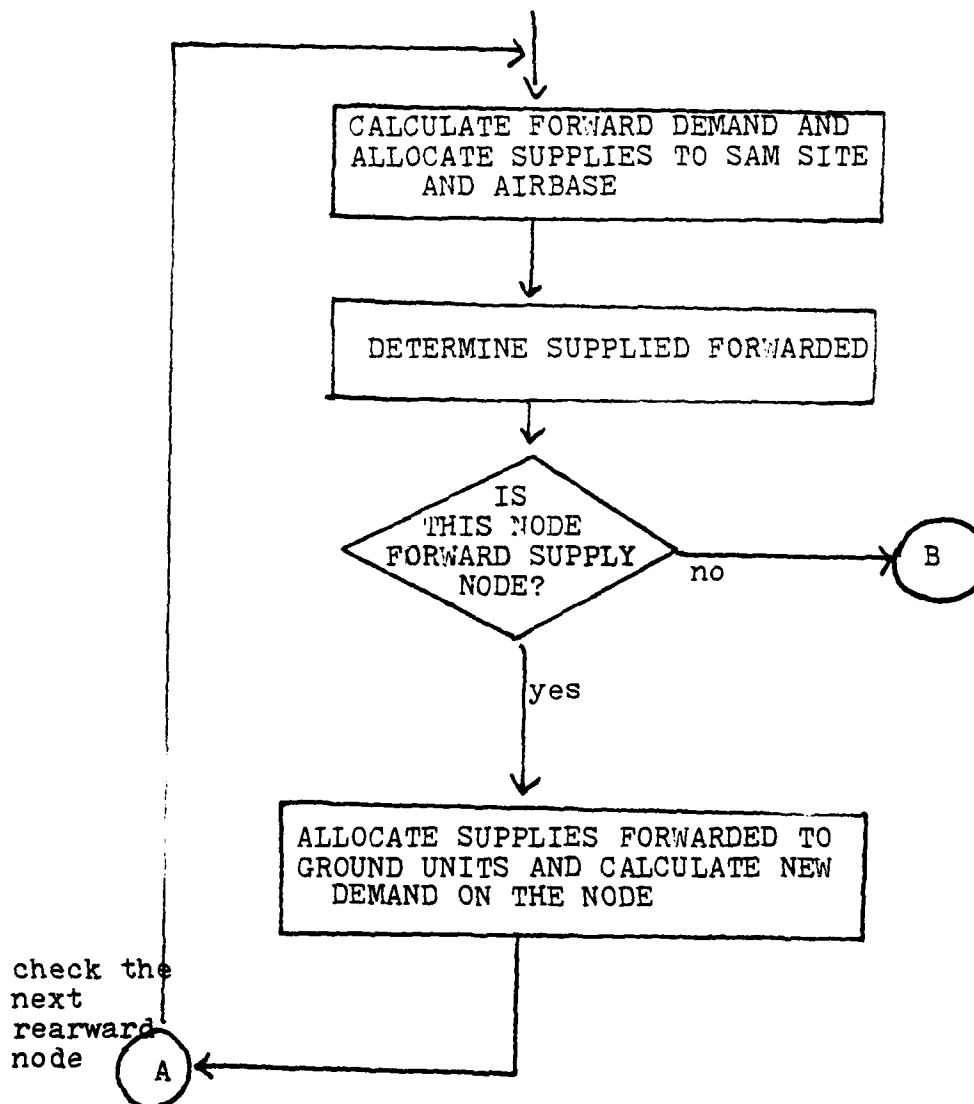
Fig. 3-6 Logical Process of Movement of Supplies and
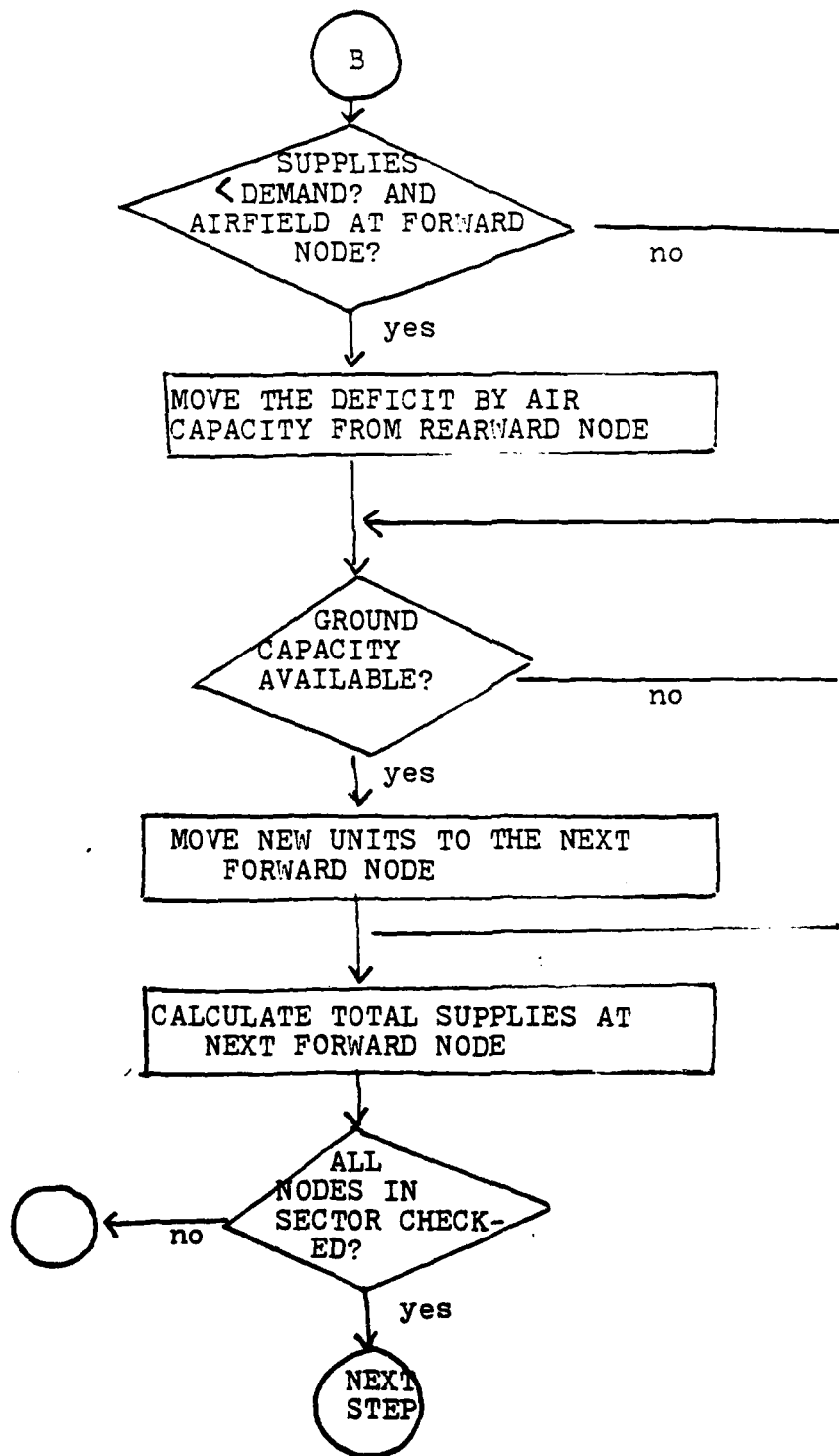   New Units

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Fig. 3-6 cont. Logical Process of Movement of Supplies and Units

remaining output capacities are used to move new units
(troops, their equipment, and authorized basic load) up to
the combat zone and to meet stockpile requirements of specific
nodes. Supplies are moved from node to node using logic
that is applied to each node in turn, beginning at the
forward supply node as shown in Figure 3-6.

The logic of the model is designed so that all
supplies and new units will be transported over ground LOCs,
if the capacities are large enough, with the use of supple-
ment air transportation. If the supplies leaving a node fall
short of the demand, because of a lack of supplies or
ground-output capacity limitations, it may be possible to
fly the deficit into the receiving node if the node has an
airfield capable of accepting the deficit, and if a node (or
nodes) to the rear has sufficient supplies and air output
capacity.

The net result for all nodes behind the forward
supply point is a shifting of supplies and new units from
one to the next. Supplies leaving the forward supply point
go to consuming units and cannot be supplemented by air
delivery. Combat units that have traveled piecemeal through
the LOC network stay at the forward supply point until they
are complete, then they are assigned to combat. In this
movement procedure all supplies and new units should, if
possible, be moved over the ground LOCs, remaining ground
output capacities are used to send new units to a more forward
node and then send supplies to meet stockpile requirements of
the forward node.

C. AIR COMBAT

1. The Tactical-Air Model

For the formulation of the rigid rules for the game
assessment, RAC (the developer of the ATLAS model) has taken
the conceptual basis of the tactical-air model to be as
follows:

> ...the tactical-air model of ATLAS is based on the premise
> that the effects of air operations can be forecast and
> that weapon systems and tactics can be evaluated on the
> basis of past experience and analytic comparison. Certain
> air operations data from WWII, the Korean War, and Vietnam
> have provided a basis from which to measure air-weapons
> effectiveness in various applications...

In this respect the model has been designed to assess the
effect of air attacks on ground combat elements, opposing
aircraft and other specific targets in three general-type
missions: (a) air-superiority mission, (b) CAS, and (c)
interdiction-type missions. For assessment purposes, the
air-superiority missions are viewed as the SAM suppression,
airbase-interdiction, and air-defense roles.

A generalized flow diagram of the tactical-air model
is shown in Figure 3-7. Daily operation of the model depends
on the air-control authority (ACA), simulated within the
tactical decision model, to assign combat aircraft to each
sector. Aircraft are assigned to sectors on the basis of
enemy ICE per sector and the overall aircraft availability.
Once aircraft are assigned to sectors, the model makes
assignments to specific airbase with the sector for a home-
base location and logical support. The combat radius of the
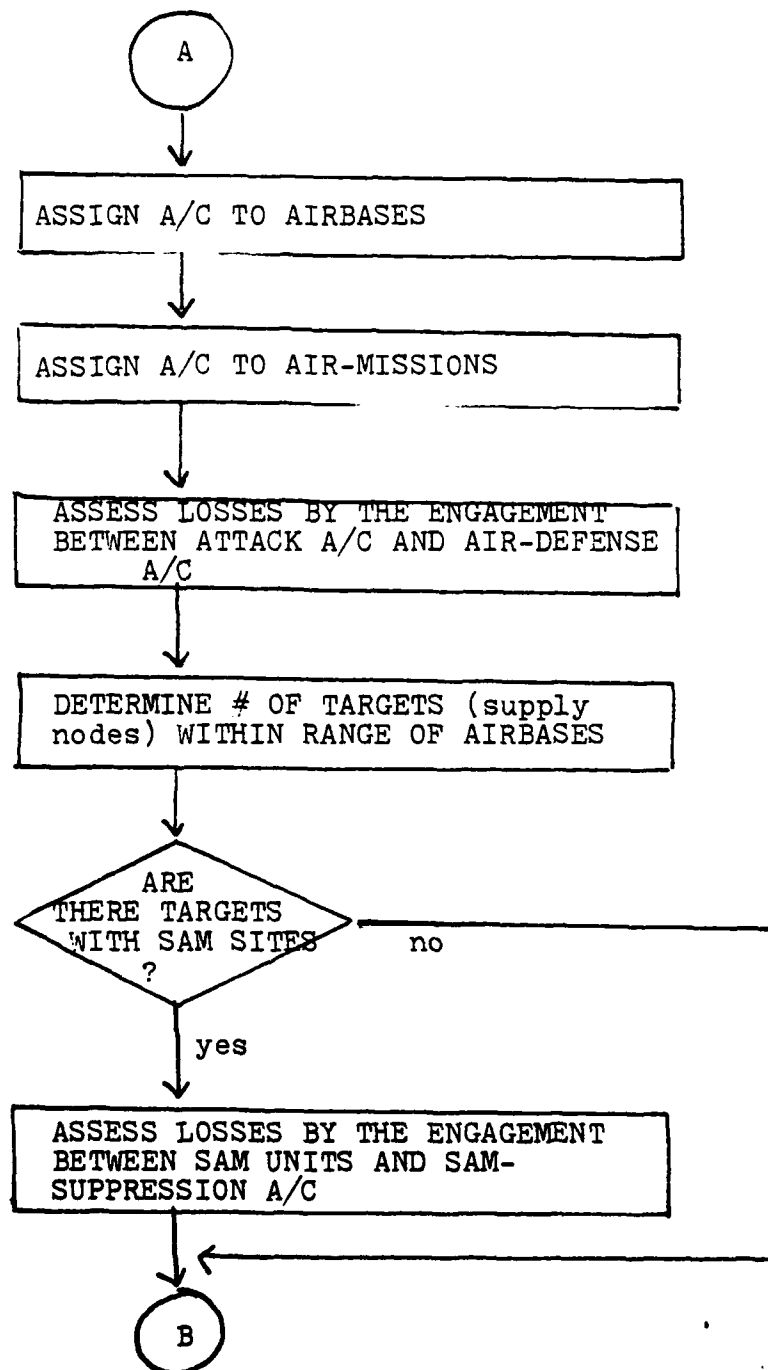
Fig. 3-7 Generalized Flow Diagram of the Tactical-Air Model
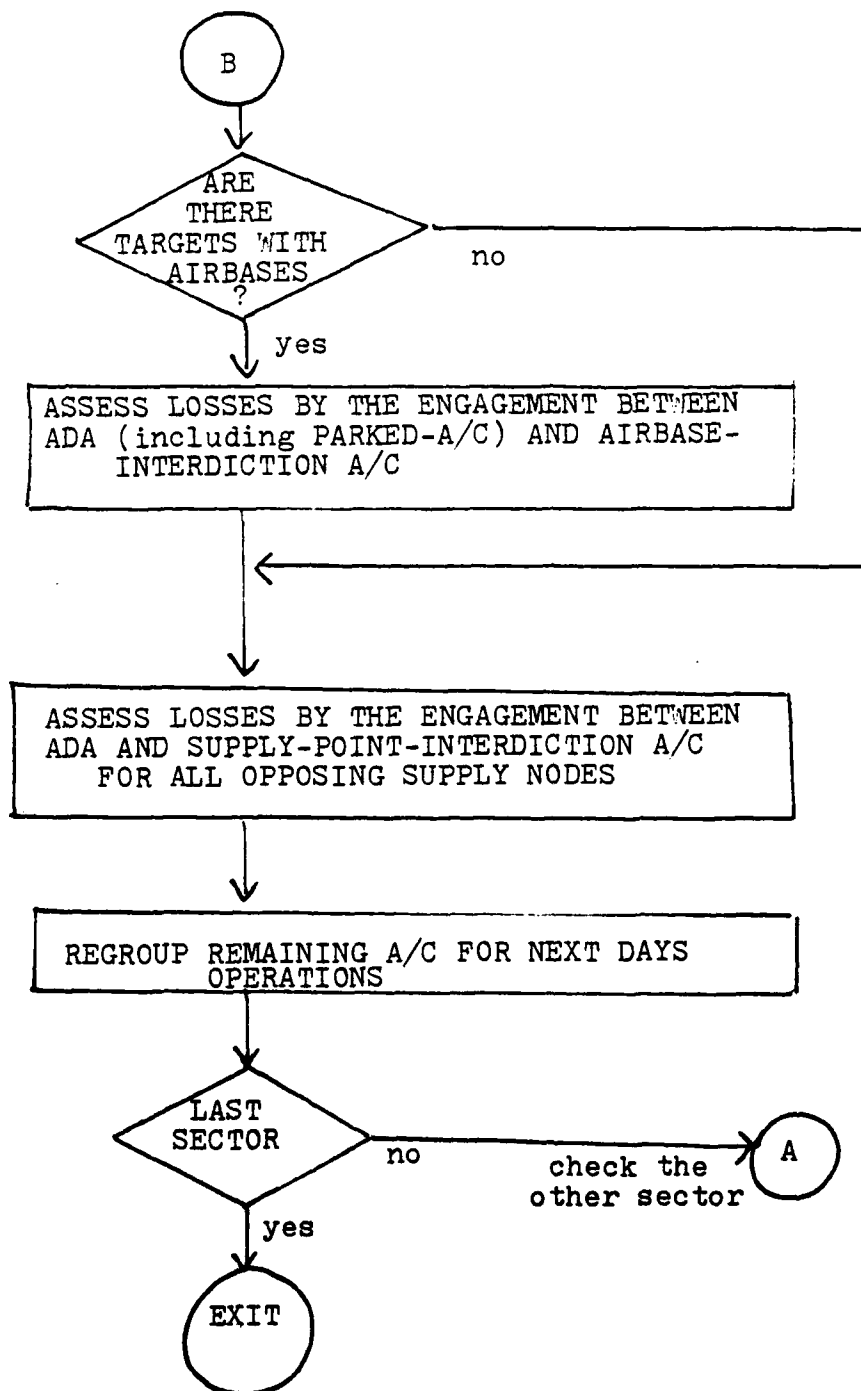
Fig. 3-7 cont.   Generalized Flow Diagram of Tactical-Air Model

aircraft determines the maximum depth to which SAM sites, and supply nodes may be interdicted. The results (losses) of engagement in the model are expressed symbolically by means of a mathematical formula based on kill probability, attrition constant, and other factors. The engagement rule in the model depends on air-mission assigned to aircraft as follows:

(a) attack aircraft[4] vs. opposing air defense aircraft

(b) SAM suppression aircraft vs. the SAM units

(c) SAM suppression aircraft vs. air defense artilllery (ADA) units associated with the SAM units

(d) airbase interdiction aircraft vs. parked aircraft at the airbase

(e) Airbase interdiction aircraft vs. ADA units associated with the airbase

(f) supply point interdiction aircraft vs. ADA units associated with the supply point.

2. Counter-Air-Defense Allocation

Counter-air-defense operations are designed to encompass SAM-suppression and airbase-interdiction missions.

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[4]Attack aircraft in the model are taken to be all other mission aircraft except air defense aircraft (interceptors): aircraft to be used on mission of SAM suppression, airbase interdiction, supply point interdiction, and CAS.

The determination of the number of aircraft assigned to each type of mission within the counter-air-defense operations is shown in Figure 3-8. An implicit assumption is made that good intelligence on the location of SAM sites and airbases is available. As shown in Figure 3-8, the model determines if an enemy airbase is within combat range of the home airbase. If none exist, all counter-air defense aircraft are assigned to interdict SAM sites within range. If no SAM sites are within range, the counter-air defense aircraft are then reassigned to air-defense, CAS, and interdiction-type missions equally.

D. GROUND COMBAT

1. The Ground-Combat Model

The main purpose of the ground-combat model is to determine the daily changes in the location of the FEBA within each sector. As various parameters are changed during the course of many plays of otherwise similar situations, comparison of the records of the movements of the FEBAs may be used as a measure of the effects of the changes. Thus the model can be used, for example, to determine the effects of changes in the rate of arrival of supplies or troops into the theater.

Figure 3-9 displays the generalized flow diagram of the logical process for the ground-combat model. The model first examines the forces assigned to combat on each side, modifies their ICE according to their present personnel or material strengths, determines which side is to be the
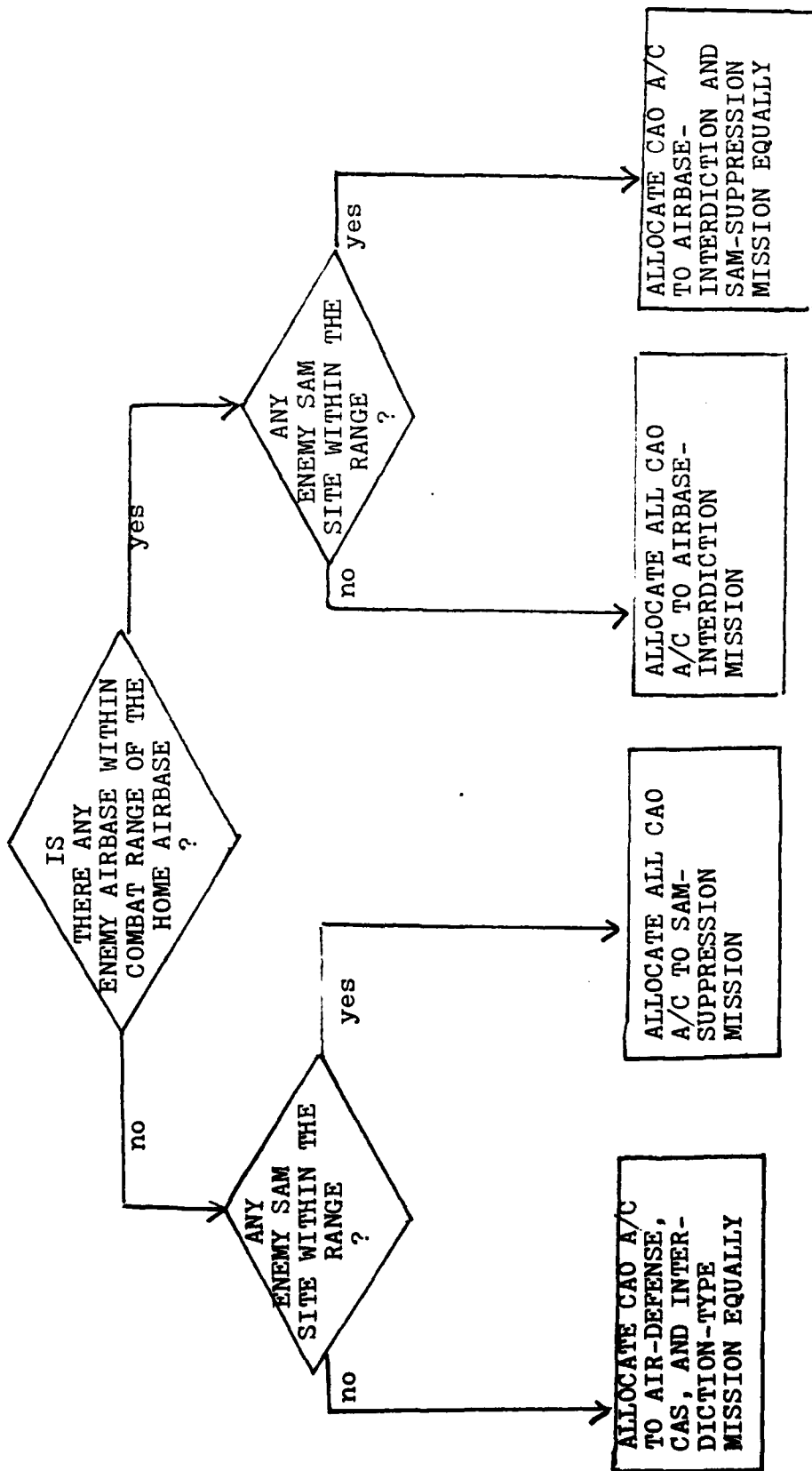
Fig. 3-8 Allocation Process of the Counter-Air-Defense (CAO) Aircraft

Fig. 3-9   Generalized Flow Diagram of the Ground-Combat Model

```
                              ( B )
                                |
                                v
              +---------------------------------+
              | COMPUTE THE TIME CONSUMED        |
              |   (less than 1 day)              |
              +---------------------------------+
                                |
                                v
              +---------------------------------+
              | ASSESS CASUALTIES               |
              +---------------------------------+
                                |
                                v
                          /------------\
                         /    TIME       \
                        /   REMAINING      \------------------->  ( D )
                        \    = 0?          /        no
                         \                /
                          \------------/
                                |
                                | yes
                                v
              +---------------------------------+
              | PREPARE THE NEXT DAY'S           |
              |  BATTLE                          |
              +---------------------------------+
                                |
                                v
                          /------------\
                         /   LAST        \
                        /   SECTOR         \----------------------->  ( A )
                        \    ?             /     no      check the
                         \                /             next sector
                          \------------/
                                |
                                | yes
                                v
                             (      )
                             ( EXIT )
                             (      )
```
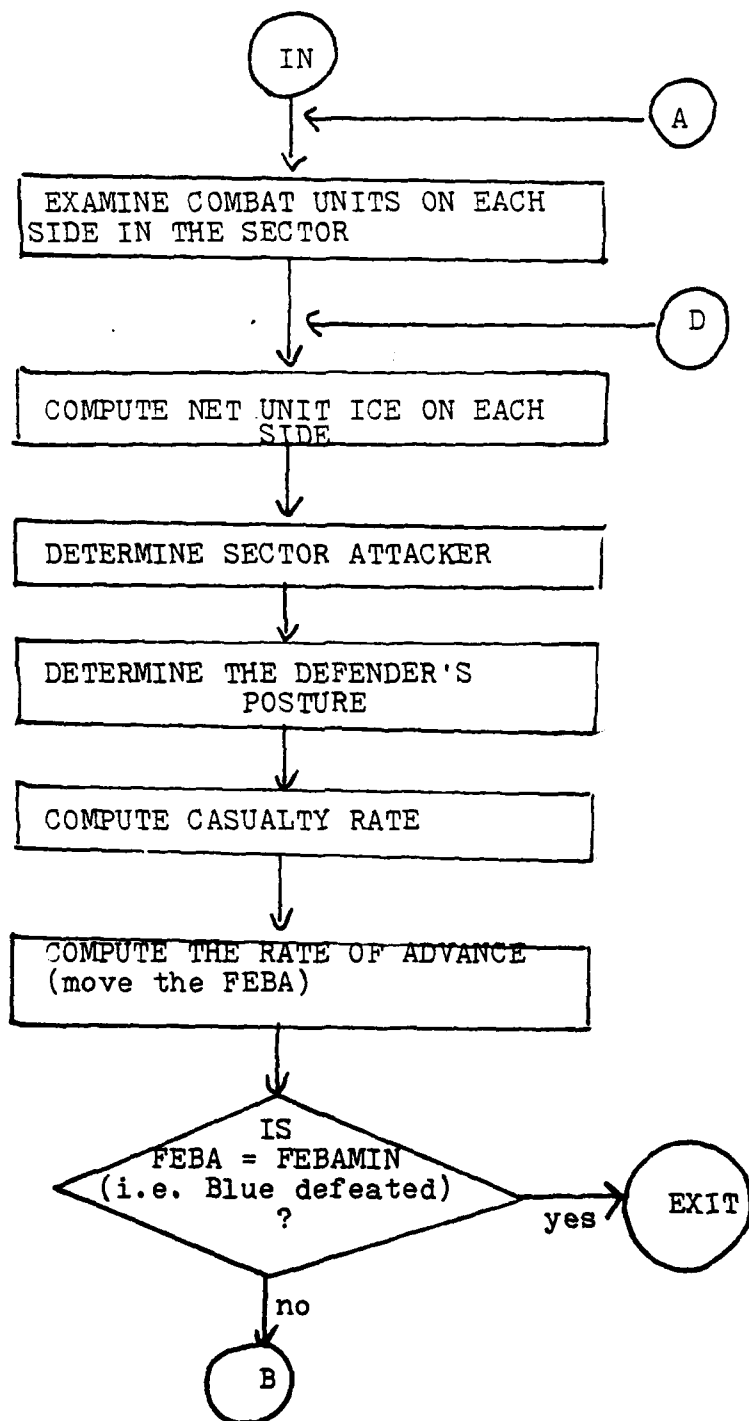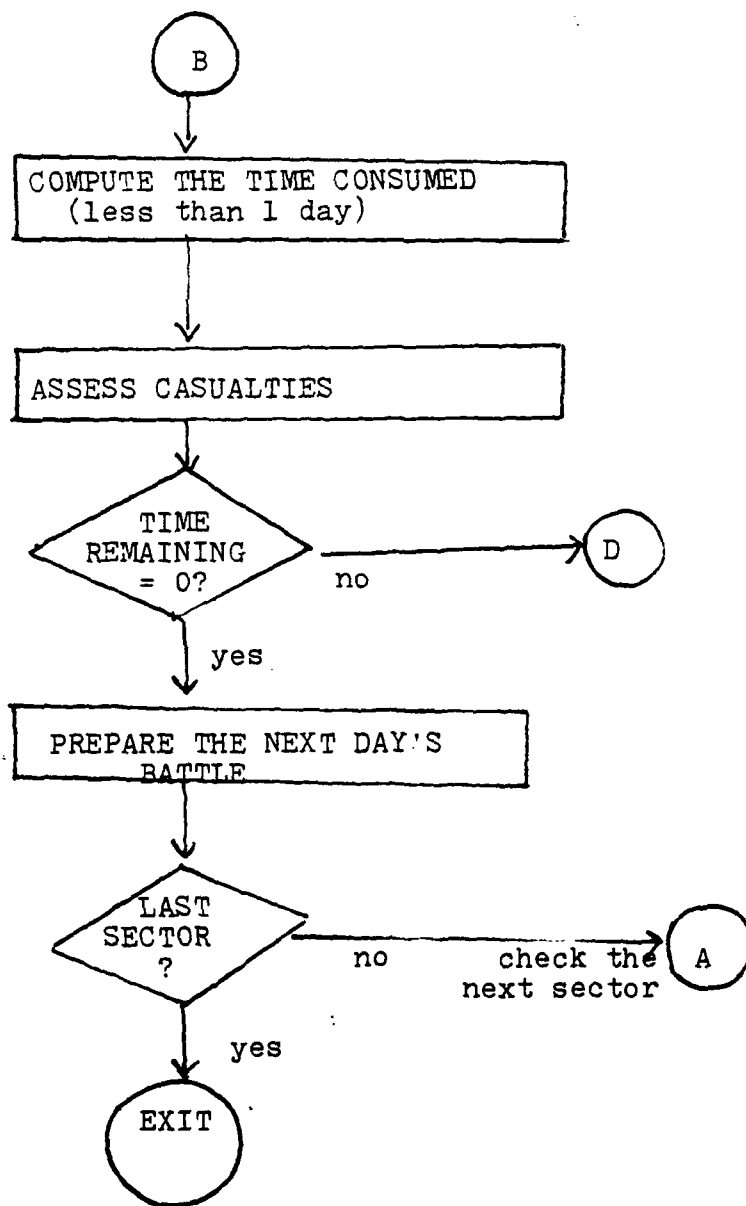
Fig. 3-9 cont.   Generalized Flow Diagram of Ground-Combat
                 Model

attacker, determines the defender's tactical posture,
assesses casualties to all engaged units, and finally computes
the distance the attacker will advance.   The flow diagram
shows the sequence of events involved in processing ground
combat in a given sector. If, in a given sector, a segment
boundary is reached in less than a day, the cycle is repeated
for that sector to account for the remainder of the day.

To conduct a play of the ground model requires that
information be available about the theater battlefield, the
troops and weapons involved, the terrain conditions, the
tactical postures, and casualty rates and movement rates for
each type of unit simulated when encountering various force
ratios.

2. FEBA Movement Routine

If there is any movement of the FEBA, it is always
in a direction that is favorable to the attacking force. The
extent of the movement is a function of the force ratio, the
terrain, the posture of the defender, and the relative ability
of the attacker to move at infantry or armored rates (see
section D of chapter V for a detailed discussion). Since the
major output of ATLAS is the daily change of FEBA, one obvious
course of action is to have a closer look at hoe the FEBA
movement routine within the model is being performed.

The FEBA movement routine is presented in Figure 3-10.
The flow diagram shows the logical process on which the com-
puter program for the ground-combat model is based. According
to the above diagram, the routine is explained by step-
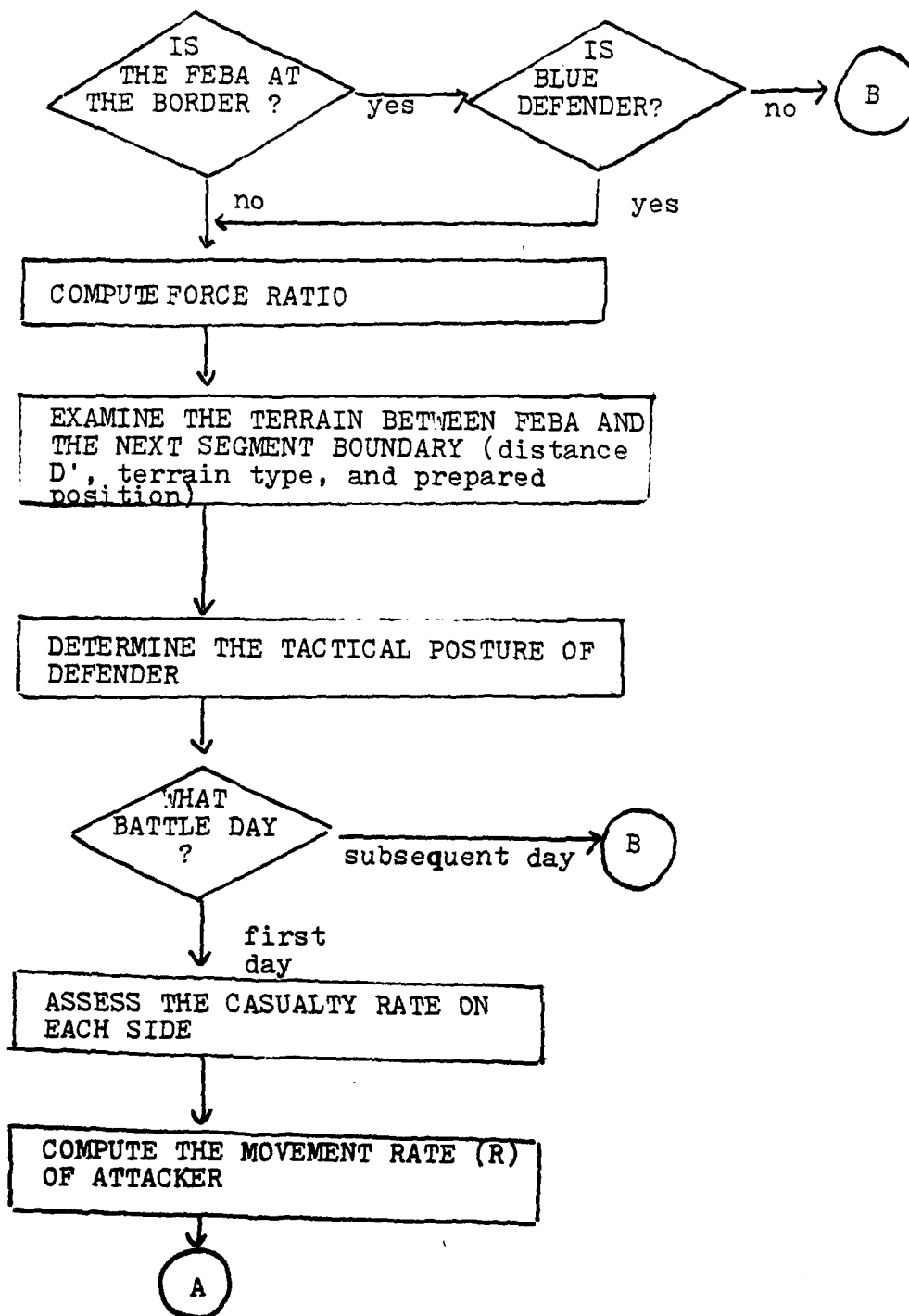procedures as follows:

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Fig. 3-10 Logical Process of FEBA Movement Routine

A

COMPUTE THE DISTANCE (D") THAT
THE ATTACKER COULD BE COVERED AT
RATE R IN TIME T (initial T=24hr)

DETERMINE THE DISTANCE (D) THE
FEBA WILL BE MOVED (D = min
(D',D"))

IS
NEW FEBA AT THE
BORDER (Blue defeated)
?

yes → EXIT

no

B

$D = D"$?

yes

ASSESS CASUALTIES
FOR 1 DAY

check the
other sector

COMPUTE THE TIME CONSUMED

ASSESS CASUALTIES FOR THE TIME
CONSUMED

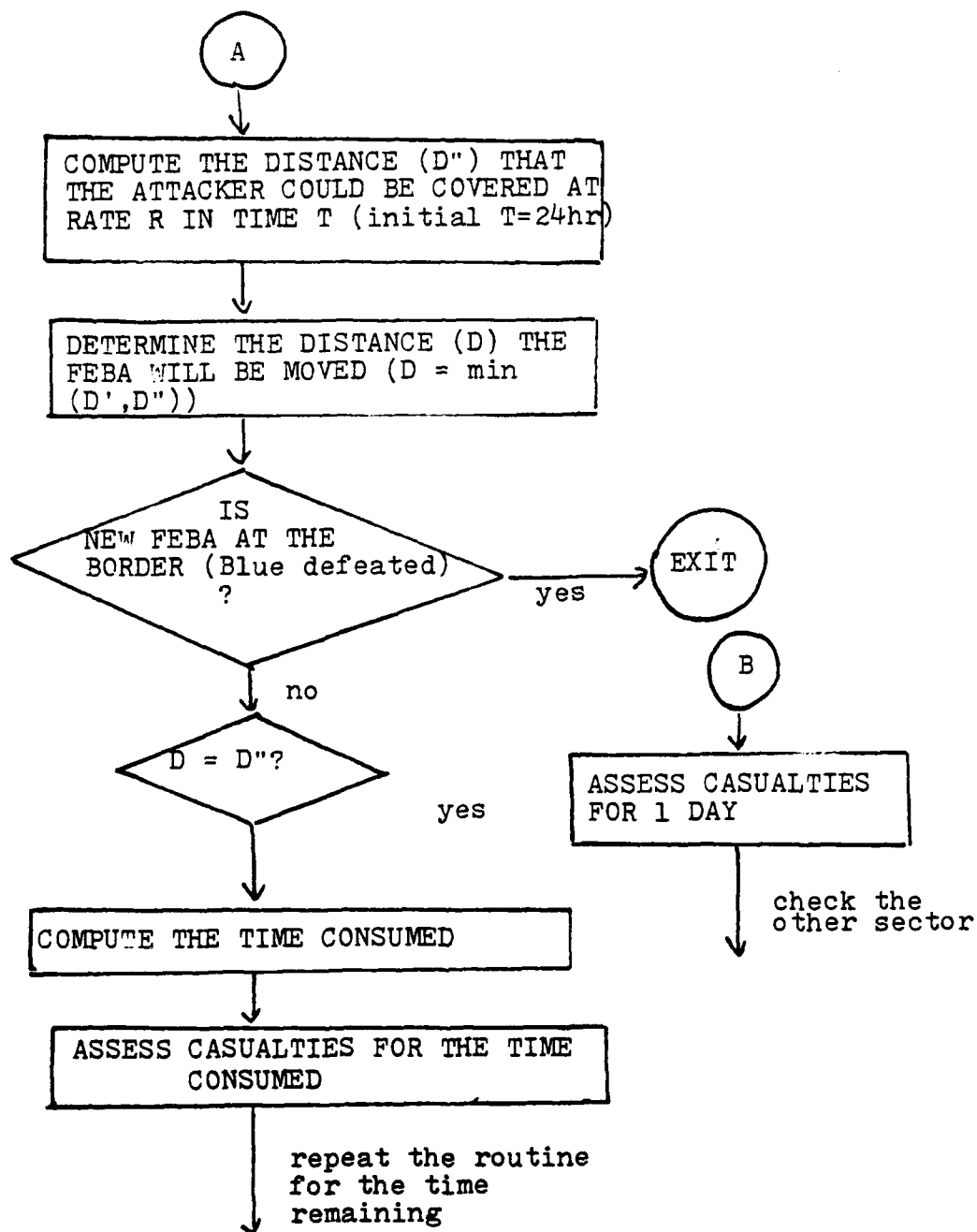repeat the routine
for the time
remaining

Fig. 3-10 cont. Logical Process of FEBA Movement Routine

Step. 1   The model first checks to see if the FEBA is at the border. If it is not and the friendly (host country) force is the defender, the force ratio is this time computed using the revised ICE value for the attacker.

Step. 2   The description of the terrain between FEBA and the next segment boundary is then examined. If it includes a record of the presence of a tactical defensive position, the appropriated posture is selected from among the first three (fortified zone, prepared position, hasty position). In the absence of a tactical defensive position the posture is determined by the average effectiveness of the attacker's and defender's units.

Step. 3   If one of the first postures is selected, the model checks to see which side prepared the position. If the current defender prepared the area, the rates of advance applicable to the determined posture are appropriate. However, if the current defender did not prepare the position, he is assumed to be in less desirable defensive conditions (meeting engagement, delaying action, orderly retirement, and disorganized retreat) and the rates of advance applicable to the next weaker posture are used.

Step. 4   The next step is to assess the casualty rates. If it is the first or subsequent (active) battle day when the attacker is attempting to advance, the appropriate casualty rate is chosen and the program goes to the step for calculation of the movement of the FEBA. If it is a subsequent (quiet) day when the attacker is exerting only enough

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effort to hold his position, a lower casualty rate is
specified and the program skips calculations concerned with
FEBA movement.

Step. 5 The next step after assessing the casualty
rates is to calculate the rate of advance. The rate is an
average of the rates for armor and for infantry according
to the relative proportions of armored and infantry units
in the attacking force.

Step. 6 The distance the attacker could advance in
the time available at that rate is next calculated. Normally
the time available will be 24 hr, but if the distance to the
next segment boundary (D'), determined earlier, is less than
the distance that could be covered in the available time at
the given rate (D"), then a segment boundary will be reached
in less than the available time. This means that a new rate
of advance becomes applicable with less than 24 hr available
on the next segment in this sector. The distance the FEBA
will be moved is set equal to the lesser of D' and D".

Step. 7 Next, the position of the FEBA is
approximately changed and the location of the new FEBA is
checked to see if it represents defeat for Blue. If it does
not, the next check is to see if the attacker has gone as far
as time allows. If he has, casualties are assessed for each
side for total time that was available.

IV. IDENTIFICATION OF MAJOR ASSUMPTIONS OF ATLAS

A. GENERAL

Theater-level combat models such as ATLAS are designed generally to predict the results of large-scale combat in terms of territory controlled (e.g., FEBA locations) and resource consumption (e.g., casualties and equipment losses), as a function of various force levels, and force employments. However, these models cannot be designed exactly to reproduce the real combat situations. Thus, they should provide such a good parallel to the real situations that they can be understood and used by the military planners. Recognizing this inherent limitation, assumptions should be made so that the model can at least give "insight" into the situation being examined.

Assumptions in ATLAS were made throughout the model to make possible the formulation of the rigid rules for the battle assessments. Actually, an assumption is a limitation only in the sen that, as a supposition, it should be verified in actual battle. Although the assumptions used in the ATLAS model are believed tobe realistic, it is unlikely that every one will prove to be valid. For this reason it is felt that proper evaluation of the ATLAS output by the users requires awareness of the explicit and implicit assumptions.

B. ASSUMPTIONS IN GROUND-COMBAT MODEL

1.   Terrain can be portrayed in an adequate fashion for movement of military units by the three classification types A, B, and C. The addition of barrier to each terrain type extends the classification to six types.

2.   The effectiveness of a barrier is deleted once it has been passed through. This assumes that all barriers are man-made and would be destroyed or removed by the attacking force.

3.   Personnel replacements can enter each day at a stated replacement rate. Thus, a unit's strength could be rebuilt to its TOE strength. Replacements are experienced personnel and can carry on with no loss of unit effectiveness.

4.   A division-sized unit in a defensive posture is considered combat ineffective and hence withdrawn from combat when its personnel strength falls below 67 percent. The level at which an attacking unit becomes combat ineffective is 79 percent, although it is not withdrawn until the 67 percent level is reached.

5.   Personnel casualties are assessed as a function of the type of unit, tactical, posture, and force ratio. The casualty values are average values reflecting only "killed in action" and "wounded in action" and were derived from historical studies.

6.   The rate of advance of division-sized units over the types of terrain played are average values derived from many situations in WWII and Korea. In using these rates, it is

assumed that the movement of future large-scale conventional war forces employing division-sized units will be similar to that in these historical situations.

7. Field artillery not organic to the combat units is considered to be in a supporting role and is reduced in effectiveness only by insufficient supplies.

8. The degradation of a unit's combat effectiveness is a function of personnel strength and supply level only and each degradation is basically a nonlinear decreasing function.

9. The battle sectors are assumed to be independent. Thus, each sector combat force is allowed to disregard its blanks.

10. Weapon firepower effects are assumed to be linearly additive with no enhancement (or degradation) included as a result of combined weapons.

C. ASSUMPTIONS IN TACTICAL-AIR MODEL

1. All active air bases and SAM sites within range of the combat aircraft are vulnerable to enemy air attack.

2. Combat aircraft are allocated to sectors from the control centers as a function of the tactical situations within sectors. The combat missions are assigned based on the enemy ICE per sector. This type of assignment is made in the model without regard to the overall enemy air threat.

3. The effectiveness of air defense artillery organic to combat divisions is reduced at the same rate as the effectiveness of the division.

4. Concurrent air-to-air battles occur with every type of tactical air mission.

5. The number of aircraft that will attack specific targets is proportional to the size or strength of the target. The types of targets and the criteria for selection are:

(a) Airfields: size of the airfield in sortie capacity and nearness to FEBA

(b) Supply nodes: size of the node expressed in total tons on hand

(c) SAM sites: number of fire units at the site.

6. It is assumed that a negative exponential assessment is an adequate expression of damage to air bases, supply nodes, and LOC as the number of aircraft per target varies. This assessment implies a point of diminishing returns when a large number of aircraft are making the attack.

7. The number of aircraft assumed to be parked at an air base and unable to scramble during a rapid can be made a function of the overall reliability factor or some similar fraction of total aircraft strength at the air base.

8. The CAS assessments assume a standard loading of munitions for CAS missions. Implicit in the assessment is the assumption that the munitions delivered on similar target elements will be equally lethal whether the munitions are delivered by artillery, mortars, or tactical aircraft.

9. The support provided the ground battle by tactical aircraft is adequately measured by adding the ICE of CAS to the total sector ICE.

10. Tactical aircraft, as portrayed by the notional aircraft, have the same combat radius for all missions.

11. Average values of input data such as kill probabilities, attrition rates, and sortie rates can be used for the entire game without invalidating the game assessments.

D. ASSUMPTIONS IN LOGISTICS MODEL

1. When less than 2 days of supplies are available in a division unit it is assumed that rationing will begin and the unit's combat effectiveness will be degraded.

2. Combat consumption of supplies is a function of the tactical posture and the type of consuming unit.

3. The resupply of deployed combat units through the LOC network takes priority over the deployment of new combat units.

4. The expenditure of SAM is a constant rate per battery based on a given level of activity.

5. The theater's capability to logistically support the land and air battle can be adequately measured by its ability to move gross tonnage from points of entry to the battle area. Interdiction losses and support-unit consumption are assessed in each sector.

6. The degradation of a unit's combat effectiveness is a function of personnel strength and supply level only.

7. Resupply of units and other supply nodes is made primarily by ground means. Aerial resupply is a secondary means and, when it is used, the radius of helicopter resupply operations is assumed to be equal to the distance between nodes.

8. No LOC restrictions exist between a supply node and a SAM site or tactical air base.

9. Port and air base facilities are assumed to be adequate to receive and discharge cargo shipments into the theater. When this assumption is not valid, incoming re-supply should be reduced to the existing port capacity.

10. Combat units moving to the forward combat zone will sustain no losses of personnel or equipment.

E. ASSUMPTIONS IN TACTICAL-DECISION MODEL

1. The allocation of combat aircraft to each battle sector is a function of the tactical situation existing in the sector: (a) Red forces advancing, (b) Red forces retreating, and (c) forces stalemate. These situations are assumed to be assignment priorities 1, 2, and 3 in the order a, b, c for the Red force and a, c, b for the Blue force. Thus, each day the tactical-decision model assigns all the aircraft available to the highest priority situation existing.

2. The assignment of SAM units to battle sectors is determined by the tactical-decision model following their planned arrival time into the theater. The buildup of SAM defenses follows the basic doctrine of deployment for the type of SAM units (short-range low-altitude SAMs.)

3. The decision model assigns a new unit to a particular sector in which the attacking force could reach a strategic phase line in minimum time. If there is no movement on the front, minimum distance becomes the criterion instead of minimum time.

V. DETAILED ANALYSIS OF FUNCTIONAL AREAS OF ATLAS

A. INDEXES OF COMBAT EFFECTIVENESS

The measure of combat effectiveness used in ATLAS is the
"firepower index" concept, called ICE (Index of Combat
Effectiveness), a number that purports to indicate the worth
of a combat unit in comparison to some standard unit. The
ICEs used in ATLAS are derived from more fundamental numbers
called "firepower scores." The modern battlefield, as con-
sidered in the theater situation of ATLAS, contains many
diverse weapon-system types that complement each other and
operate as combined-arms teams. RAC has developed this
firepower-score approach to aggregate the many diverse combat
capabilities of such a heterogeneous military force into a
single scalar measure of combat power.

A prominent feature of the ATLAS model in comparison to
other theater-level models is the use of a firepower index
concept which represents the "combat potential" of a military
unit. As Stockfisch [5] has emphasized, we should use the
term _firepower score_ to refer to the military capability or
value of a specific weapon system and use the term _firepower
index_--which is obtained by suming scores--to refer to the
military capability or value of some aggregation of diverse
weapons. Thus, the firepower index of the X force, denoted
by I_x, is given by

$$I_x = S_i N_i \quad,$$

where S_i denotes the firepower score of the <u>i</u>th weapon system and N_i denotes the number of <u>i</u>th weapon system (see Table I).

The firepower indexes, promulgated by the Army Combat development Command, drew upon concepts and data produced from ballistics research conducted by Army laboratories. One concept that grew out of that research was that of the "lethal area (LA)" of the projectile. By knowing the lethal area of a type of round of ammunition (given as a function of personnel posture) and multiplying by an assumed daily expenditure rate for this type of ammunition, there results a firepower score in terms of lethal area per day. When each of the firepower score for all the weapons of the division have been added, and then normalized about the firepower index of the standard unit, the result is the ICE value for the unit considered.

At this point, firepower scores like those in Table 1 raises a question: How are they derived? In actuality, varying amount of "subjectivity" are involved in the development of such a firepower score. Stockfisch [5] comments on that:

> ...the index-numbers of different weapons could be
> determined through separate inquiry: (a) by reference
> to organizational tables of equipment (TOE) or order
> of battle estimates, (b) as a function of assumed or
> planned mobilization and deployment rates, or (c) by
> assumption...

TABLE 1

HYPOTHETICAL EXAMPLE OF DETERMINATION OF A
FIREPOWER SCORE FOR A COMBAT UNIT[a]

Weapon	Number	Firepower Score	Total Contribution to Firepower Index
Rifle, M-16, 5.56mm	6,000	1	6,000
MG, M-60, .30 cal	150	6	900
MG, M-2, .50 cal	250	10	2,500
Mortar, M-125, 81 mm	50	20	1,000
Howitzer, M-109 (SP), 155mm	50	40	2,000
Howitzer, 8"	8	30	240
Tank, M60A2	200	100	20,000
TOTAL FIREPOWER INDEX			32,640

[a]Firepower Index for U.S. Army's 7th Infantry Division

Source: "Attrition Modelling," 1979, Table V, Chap 6 [4]

Reflection about the firepower index generated such criticism of the concept, and stimulated attempts to formulate alternative index number concepts.[5] What is the nature of the empirical data bearing upon these subjects? What is its quality? What does much of the data really mean? Before the use of the ATLAS model, we must ask ourselves those kind of questions because one consequence of this question-raising has been to stimulate less aggregative approaches to model the subject. Actually, firepower-score approach of ATLAS has sought to capture the seeming substance of much data.

ATLAS and other models used for NATO planning that employ the firepower-score approach, however, are currently widely used in the United States. Taylor [4] comments on that:

> ...military planners apparently used the firepower-score approach for at least thirty years to plan operations and to plan and control tactical exercises. Although the origins of using firepower scores for these purposes are somewhat obscure, they are still in use today. Furthermore, it appears as though such use of firepower scores in planning was the origin of their use by operations researchers in modelling large-scale ground combat...

> ...although it has received varying amounts of criticism from different sources, the firepower-score approach is used by essentially all currently operational large-scale ground-combat models...

As pointed out in the Introduction, we need to note that recent documents by the SAGA [17] [18] identifies there was a significant increase in the frequency of the use of ATLAS: 50 times per year as of 1975; 600 times per year as of 1977.

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[5]Prominent in this effort were the weapon effectiveness indexes (WEIs), which when weighted, were converted into scores, or weighted unit values (WUVs), assigned to combat units. See Lester and Robinson, "Review of Index Measures of Combat Effectiveness," 1973 (Xeroxed).

Firepower indexes in ATLAS are used as a surrogate for
unit strength to assess casualties and determine FEBA
movement. A major factor used for such assessment is the
"force ratio" which can be constructed using the firepower
index. Here, the term "force ratio" means the ratio of the
attacker's firepower index to that of the defender.

This, Force Ratio = $S_i N_i / S_j N_j$

where the S_i, S_j are firepower scores, and

$\qquad$ N_i, N_j are the number of weapon system type i

$\qquad\qquad$ (attacker) or j (defender)

For example, the 7th Infantry Division would have a firepower
index of 32,640 as shown in Table 1. If an attacking enemy
group were to have a firepower index of 146,880, then we
have a force ratio of 4.5 (the attacker/the defender). The
force ratio in ATLAS directly affects determination of the
casualty rate and movement rate. A more detailed discussion
of the relationships between the force ratio and those two
factors is given in the following sections.

B. CASUALTY RATES

The current ATLAS model requires the casualty rate data
of combat activities at division level, but useful fundamental
numbers on casualties are quite scarce. "The Staff Officer's
Field Manual," FM 101-10[6], the primary source of authoritat-
ive numbers regarding casualties, presents a considerable

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[6]Dept of Army, "Staff Officer's Field Manual: Organi-
zational, Technical, and Logistical Data," FM 101-10, Jan 66.

range of rates. A RAC paper[4] also gives many examples of casualty rates that have occurred historically so far as can be determined from available records. Much information is there presented about both US and European unit's casualties under various circumstances in WWII and Korea. However, the weakness of this data was that it gave casualty rates as a function of posture but independent of force ratio.

New data have later become available that presented historical casualty rates as a function of type of combat engagement and force ratio. These data were a result of a substudy done for RAC by the Historical Evaluation and Research Organization (HERO).[7] The HERO casualty data are now being used in ATLAS.

Table 2 shows the casualty rates for each of the right postures recognized by the FM 101-10. Figure 5-1 represents an initial expression of casualty data as a function of tactical posture and force ratio from the HERO data. In each representation the rates are percentage casualties per division unit per day. Those casualty rate curves in Figure 5-1 are typically plots of fractional casualties per unit time versus the force ratio for different engagement types. Thus, two such plots like those curves are used to assess casualties, one curve for the attacker and one curve for the defender.

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[7]Historical Evaluation and Research Office, unpublished notes, Jun 66.

TABLE 2

CASUALTY RATES FOR ATLAS (%)

Posture	Attacker		Defender	
	Infantry Division	Armored Division	Infantry Division	Armored Division
Fortified zone	6.6/3.5	5.5/2.9	3.5/1.9	2.9/1.6
Prepared Position	4.1/2.2	3.4/1.8	2.2/1.3	1.8/1.1
Hasty Position	4.1/2.2	3.4/1.8	2.2/1.3	1.8/1.1
Meeting Engagement	2.7	2.3	1.8	1.5
Delay action	1.6	1.3	1.0	0.8
Organized retirement	1.6	1.3	1.0	0.8
Disorderly retreat	1.6	1.3	1.0	0.8
Holding	1.0	0.8	1.0	0.8

the first day/the subsequent days

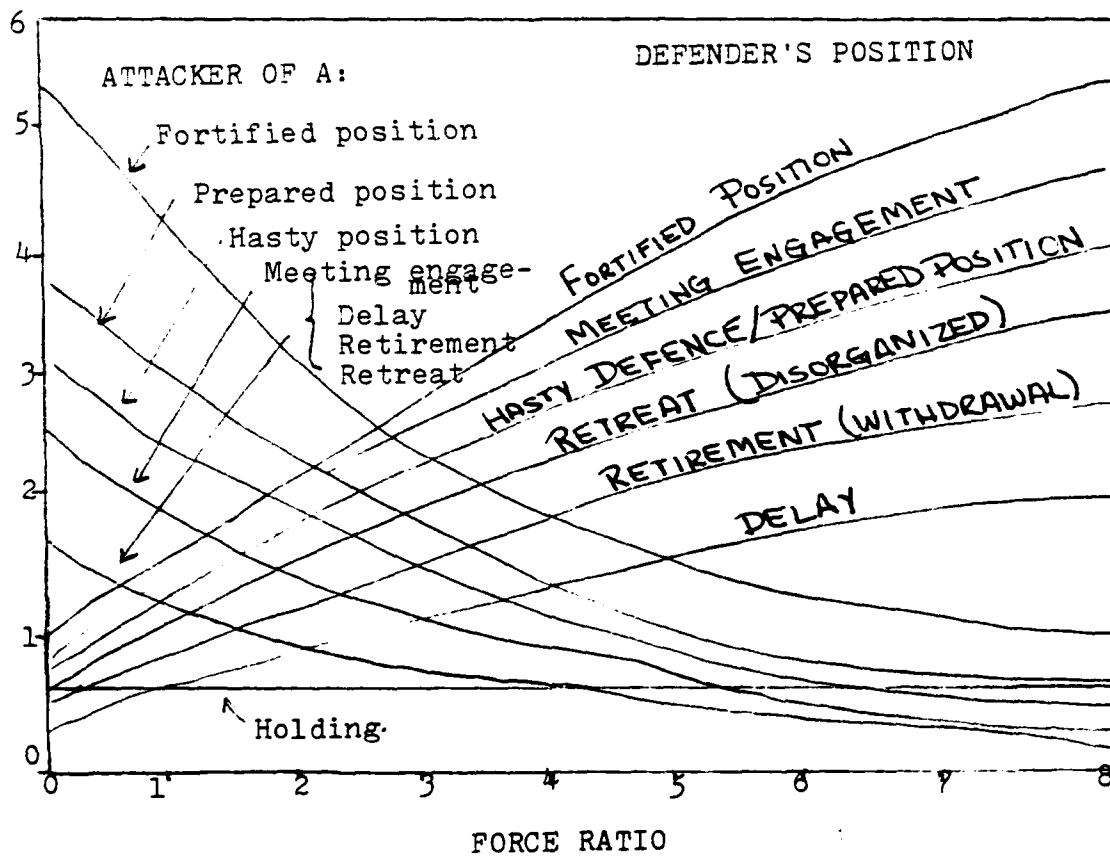SOURCE: "Computerized Quick Game," 1967, Table 1, Chapter 1 [2]

Fig. 5-1   Division Casualty Rates as a Function of Force
Ratio

The use of ATLAS in many different gaming situations, frequently required changes to the casualty rate curves, encoded in the program as constraints. This procedure led to repeated program changes which were inefficient and confusing. Consequently, the casualty rate data in ATLAS have been now removed as program constants and are treated as input. This is one of the latest modifications of ATLAS for improvement in the treatment of casualties (including some other model parameters).[8] Thus, the modification of ATLAS requires that the player input the casualty-rate curve data for both the Blue and Red sides (see [10] for instructions on how to do this).

The daily casualties may be taken as a measure of the combat output assessed by ATLAS. Thus, there is a strong requirement for valid daily casualty rates. It should be clear that with today's highly mechanized forces, "material casualties" will become the dominant factor. It seems quite clear that the casualty rates vs. force ratios currently in use have not been validated at all and are very suspect. Furthermore, there appears to be little prospect of obtaining validation of them from historical data. Scientific validation of historical results for opposing forces also appears

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[8]"Modifications to ATLAS (ATLAS-M)," CAA-TP-74-3, July 1974: The ATLAS-M project (Modification to ATLAS) was undertaken in order to improve the ATLAS model by the Review Methodology Working Group of the OSD/Army NATO Land Force Requirements Review Steering Committee in August 1973.

to be unobtainable, and we must live with that fact. Let us note recent comments on this point. It is stated on p. VI-13 of [7] that the historical casualty data are notoriously incomplete and probably inaccurate as well. It is, however, stated on p. 53 of 12 that until better historical data is available, the standard functional relationships (now used in ATLAS) between force ratios and percent casualties must still be used. What remains as justification for the rates used is "military judgement."

C. UNIT EFFECTIVENESS

This Section is concerned with the analysis of the unit-effectiveness concept used in ATLAS. In determining how effective a combat unit is on a given day, the current ATLAS model assumes that its effectiveness can be measured as function of the present casualties to the unit, the level of the unit's supplies and equipment, and the particular activity of the unit--attacking or defending. We shall discuss a unit's degradation of combat effectiveness both due to personnel casualties and due to lack of supplies.

The ground-combat model of ATLAS requires the exact percentage of casualties to consider a combat unit to be "ineffective." Actually, to determine at what point a combat unit becomes ineffective is a difficult procedure. In the ground-combat model this is accomplished by the "effectiveness curves," as shown in Figure 5-2, which take into account the effects of casualties. The effect of a given casualty level is shown to be greater on an attacking unit than on a
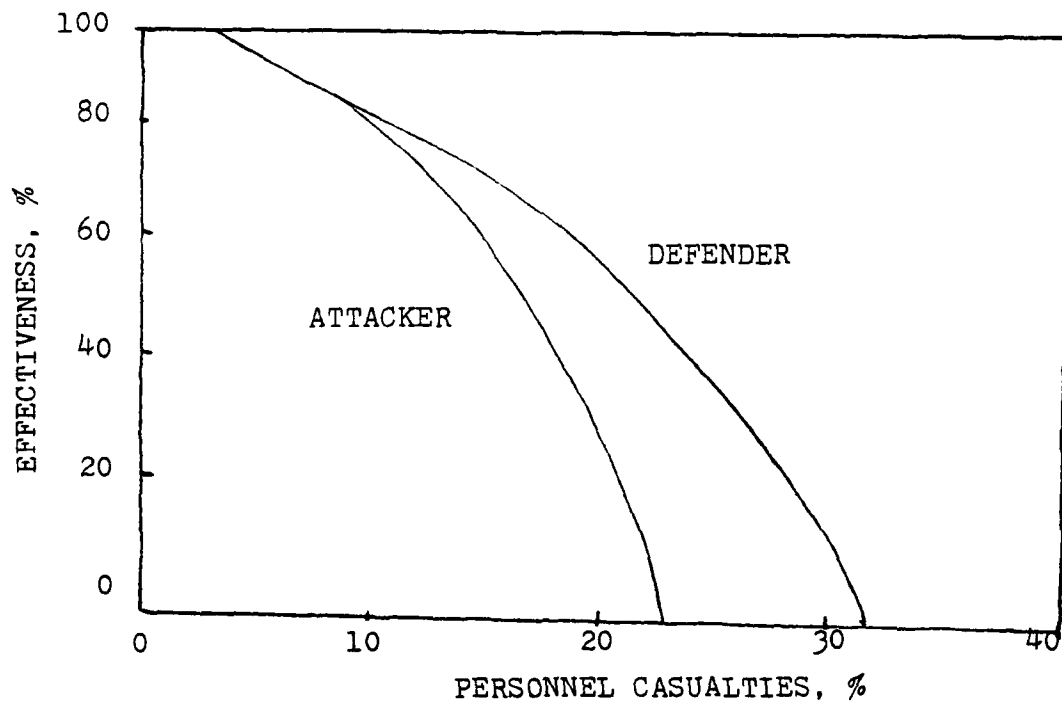
Fig. 5-2 Unit Combat Effectiveness as a Function of
Personnel Casualties, Division Level
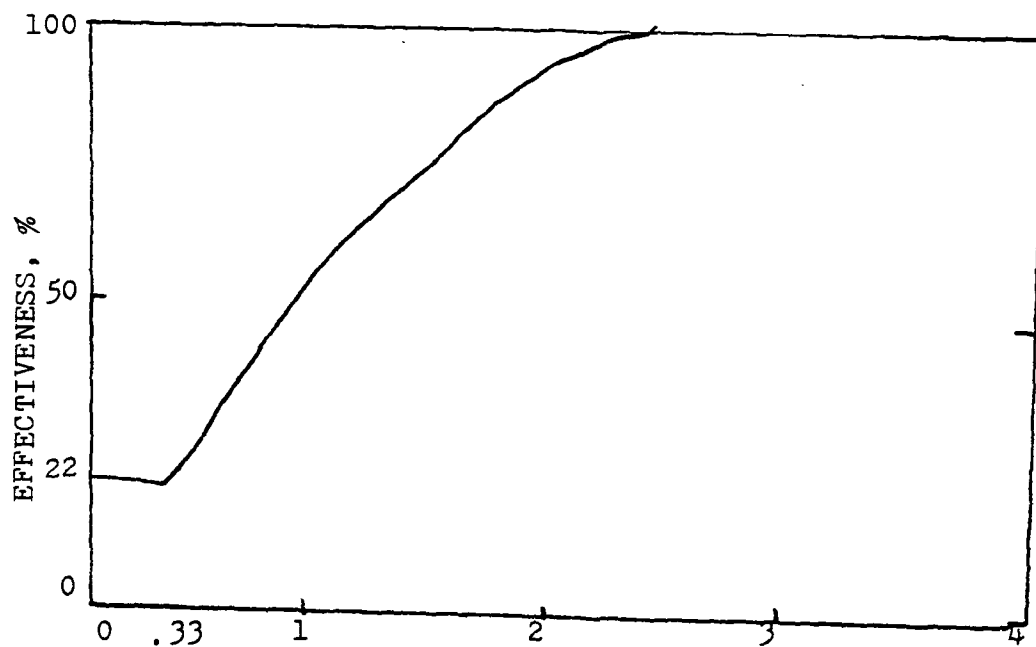
Fig. 5-3   Degradation of ICE as a Function of Days of
           Supply on Hand

defending unit. This is because an attack normally requires rapid movement, good coordination, and higher organizational integrity. Therefore, a defending unit can accomplish its task more effectively than an attacking unit having the same percentage of casualties.

The reduction in combat effectiveness is not directly proportional to the percentage of casualties. A small percentage of casualties in a full TOE unit has, on the average, a negligible effect. However, a small additional percentage tends quickly to affect the unit's effectiveness. For conventional battle this is due primarily to the usual distribution of casualties, the critical factor being that infantry, mainly in front-line units, suffers more than 80 percent of casualties.

The logistics model in ATLAS assumes that the unit's combat effectiveness will be degraded when the supplies on hand go below a stipulated 2-days level in a division unit. This reflects the fact that when the general level of supplies is low in a large unit like a division, some of the smaller component units will be short of supplies and will begin "rationing." It is felt that a unit's degradation of combat effectiveness is not a linear function of the amount of supplies on hand. The type of degradation used in the logistics model of ATLAS is shown in Figure 5-3. This curve is represented in tabular form in the input data. The equation of the curve shown in Figure 5-3 is given by:

EFFECTIVENESS (%) = 100 ($\frac{4.5\ N - 1}{3}$) 0.6 , for 2/9 N 2.0

where N = number of days of supply with the division.
The equation may easily be changed if a more acceptable
degradation function becomes available.

As discussed in the previous section, the firepower index
for each sector is simply the sum of the firepower scores of
the TOE weapons in the sector and the casualty rates are
determined as a function of force ratio,constructed using
the firepower index. Given here is the fundamental criticism
for the concept of determining a combat unit effectiveness as
a function of casualty rates. No matter how sophisticated is
the calculation of the firepower of individual weapons, the
system will be "inadequate," since the other properties of
the unit containing the weapons are not taken into account.
At this point, RAC has recently commented that considerable
research which seeks to establish the combat effectiveness
of all the attributes of a unit is "justified." [7] RAC went
on to point out:

> ...an effective approach to this problem will involve
> appropriate games and simulations. For example, the
> properties of a division for use as input to a
> theater-level combat model (such as ATLAS) should be
> investigated with a division-level game or simulation...

In principal, a set of computer assisted division-level games
could be run and the output of these games processed for use
in substitution for the current ATLAS model. However, if we

wish to obtain the ATLAS inputs from a division-level model,
will be necessary to transform that model into a rapid
playing, pure-computer simulation.

ATLAS results are very sensitive to assumptions regarding
the degradation of unit effectiveness as a function of
casualties incurred. The proper number of replacements
instantly bring the unit up to full combat capability, and
supply level. The effectiveness value finally used is the
minimum of the value due to casualties or the value due to
lack of supplies. Certainly, as pointed out previously, other
factors such as unit morale, mobility, external situation,
vulnerability, etc. affect unit effectiveness. It is
essential that some effort must be devoted to defining
these factors and the manner in which they affect unit
effectiveness.

D. RATES OF ADVANCE

The major output of the ATLAS model is the daily advance
of the attacking force in a sector. In other words, a
prominent feature of the ATLAS model is to use a force-ratio
approach to determine the advance of the FEBA during each 24
hour period. The attacker's rate of advance in each sector
is determined as a function of (a) the attacker-to-defender
force ratio, (b) the posture of the defender, (c) the mobility
of the attacker, and (d) the condition of the terrain. In
most cases, the force ratio in each sector is calculated at
the end of fixed periods of combat activity and the

corresponding attacker advance rate is then determined.
This rate is assumed to prevail until either the next battle
period is over, or the posture of the attacker or defender
changes or the terrain type changes. Since movement is
expressed as an attacker rate of advance, a continually
moving FEBA results.

In the ATLAS model the firepower-score system yields a
force ratio which is intended to be a refined measure of
combat power based on weapons and independent of the
national origin of the combat unit or its organization,
doctrine, and strategy. As stated in Section A, the force
ratio is simply a pure number obtained by dividing a
numerical measure of the combat capability of the attacker by
a similarly derived measure of the defender. In ATLAS, this
combat capability is called an ICE but other measurement
schemes may be used just as readily if desired.

Tactical posture must be recognized as a distinguishing
characteristic to determine rates of advance. Seven choices
of posture are open to a defender. ATLAS computes the posture
of the sector based on the ratio of the effective percentages
of both sides, attacker to defender. The formula[9] given on

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[9] Posture value = $3 - (E_a (1 + \min (3, 4 R)))$

Where the term E_a indicates the condition of the attacker, such
that $E_a = 1$, when attacker's effectiveness is nonzero. The
expression R is an average effectiveness ratio such that

$$R = \frac{\text{average effectiveness of defender}}{\text{average effectiveness of attacker}}$$

When the effectiveness values are equal and nonzero, the
posture calculated is 4 -meeting engagement.

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page 15 of [2] produces the following postures for given
effective percents. It must be stressed that the ratio is
of percentages and the actual strengths of the sector only
determine which side is the attacker.

A is attacker percent effective

D is defender percent effective

Posture
Value

8	if	D = 0		holding
7	if	0 D	.25A	disorganized withdrawal
6	if	.25A D	.50A	organized withdrawal
5	if	.50A D	.75A	delay
4	if	.75A D		meeting engagement

ATLAS also simulates any of three postures that involve the
preparation of an area. They are the defense of a fortified
zone, of a prepared position, or of a hasty position. The
location of such prepared areas must be given as an input to
the model.

The mobility of the attacker is described as "infantry"
for those combat personnel who must walk or "armored" for
those who can ride. The rate used in the actual calculations
are proportioned on the basis of the number of infantry
battalions and armored battalions in the division. If a
division had 50 percent infantry battalions and 50 percent
mechanized battalions, the movement rate would be an
average of the infantry and armored rates given. At this

point, General Research Corporation (GRC; [3]) has a
question on 2-level mobility based on whether the force is
mechanized:

> ...providing only 2 levels for mechanization is considered
> to be inadequate. In NATO all the units are mechanized.
> Thus, the mobility is not the distinguishing factor in
> determining rates of advance. What makes the difference
> is how many tanks there are...

It is, rather, considered that both Blue and Red should have
the percentage of "vehicles" in their units explicitly
recognized.

The condition of the terrain also affect military
movement. The model identifies three types of terrain
(described in Chapter 2) and in any type terrain there may
be man-made barriers (natural barriers are not considered
in the model). Thus, six types of terrain-barrier combin-
ations are simulated in the model.

Combining all these levels - 2 mobility levels, 6 terrain
levels, and 7 posture levels - yields 84 data cards. For
example, Figure 5-4 shows the daily rate of advance for an
armored unit attacking in terrain type A, no barrier, against
various defense postures. Table 4 also shows those data of
the same situation as Figure 5-4. These rates were derived
from basic data[10] which were translated into miles per day
normalizing against historical daily rates in WWII and Korea
and by making appropriate adjustments for the factors of
posture and terrain.

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[10]The data in "Arms Control Study," RAC-T-453, published
by the Army War College, 1965.

Use of ATLAS in gaming situations frequently required a change in "movement-rate tables," encoded in the pre-modification program as constants. In the modified ATLAS model these data are treated as separate input. This modification simplifies user procedures and provides clearer managerial understanding and control of variations of movement rate data. Thus, the model allows the player to input the movement rates and critical force ratios. It also sets the posture based on the force ratio. The user inputs the range of force ratios to be used for each posture. This means that posture, casualties, and movement will all be based on force ratio.

To summarize, ATLAS uses a force-ratio approach for the modeling of movement. The rate of advance in ATLAS is determined on the basis of assumed relationships between force ratios and rate of advance which are furnished as inputs. Actually, those rates are the attacker's rates of advance for division-sized combat units in a variety of defender postures, in a number of different terrain types and across a wide range of attacker-to-defender force ratios. The values of the rates of advance used in ATLAS are based on WWII and Korean data, but the connection is extremely tenuous, not to say non-existent. In a very revealing expose of the origins of the rates used, the Model Review Committee [7] shows just how they have been modified and reincarnated through the years. One of the severe critiques of the validity of the firepower score is also given by Bonder [6]:

TABLE 3

ARMORED DIVISION MOVEMENT RATES, TERRAIN TYPE A, NO BARRIERS
(In miles per 24 hr)

Force Ratio	Fortified Zone	Prepared position	Hasty position	Meeting engagement	Delaying Action	Orderly retirement	Disorganized retreat
0.5	-	-	-	-	-	0.00	0.00
1.0	-	-	-	0.00	5.20	13.00	15.00
1.5	-	-	0.66	2.90	8.30	16.00	18.10
2.0	0.23	0.86	2.70	5.60	11.00	17.40	20.00
2.5	0.56	2.00	4.00	7.30	13.00	18.50	20.80
3.0	0.90	3.10	5.50	8.90	14.00	18.90	21.50
3.5	1.30	4.00	5.40	10.30	15.00	19.20	21.90
4.0	1.60	4.70	7.80	11.60	16.00	19.50	22.20
4.5	2.00	5.35	8.65	12.40	16.50	19.80	22.35
5.0	2.40	6.00	9.50	13.00	17.00	20.00	22.50

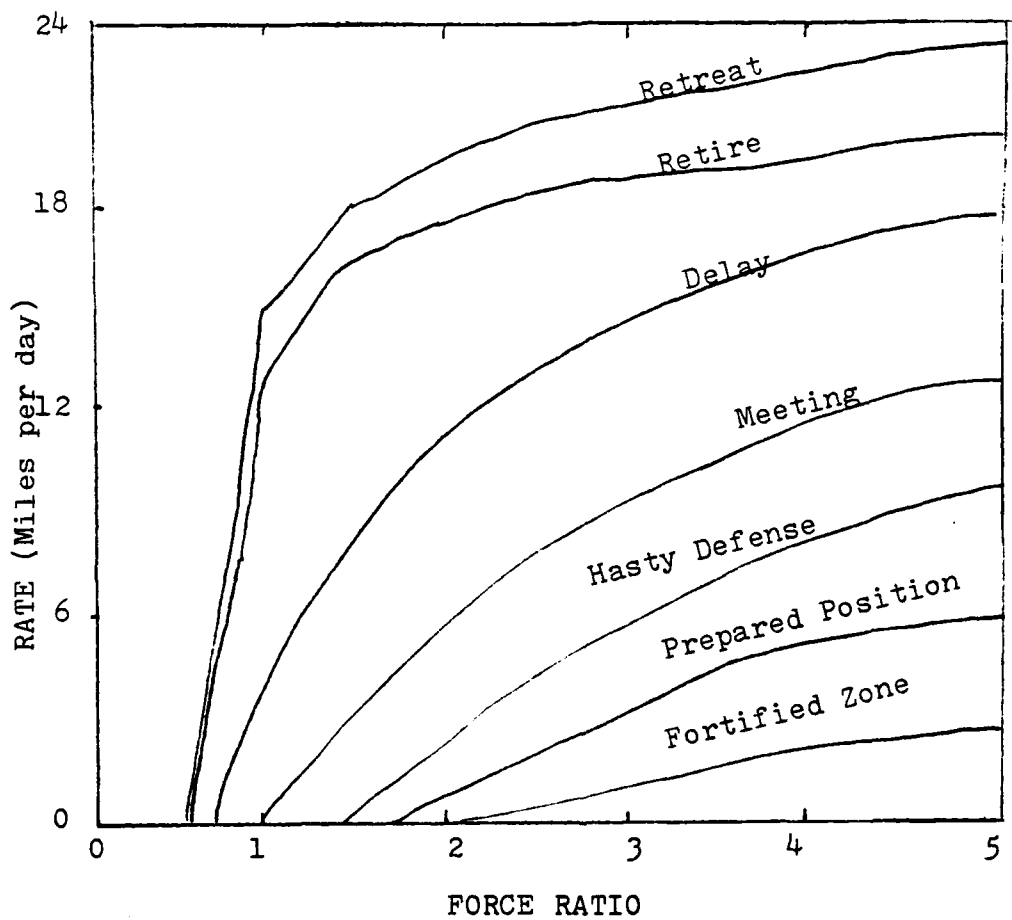SOURCE: "Computerized Quick Game," 1967, Table 5, Chap 1 [2]

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Fig. 5-4   The Daily Rate of Advance for an Armored Division
Attacking in Terrain Type A, No Barriers

...it is important to note that (a) these models (employing the firepower-score concept) are based on WWII data which is "questionable" for today's and future systems, and (b) they cannot realistically determine who is attritted in the war since the theory is not structural...

The historical or scientific validity of the rates of advance in these force-ratio models such as ATLAS is a major problem, as yet unsolved. Let us finally note a comment given by Rex Goad [19]:

...the only question that remains is how best to use the available military judgement. This, I suggest, is the only readily available validation, soft and uncertain though it undoubtedly is...

...there is an alternative course of action--namely, to stop using gaming methodologies which incorporate unverifiable military judgement. I would accuse those analyst and military planners who would wish to adopt this course of action of being totally unrealistic and unconstructive...

E. PERSONNEL REPLACEMENTS

ATLAS is also highly sensitive to the rate of personnel replacements. Initial design was that ATLAS computes replacements based on an input percentage of TOE strength. Hence, the unit's shortage was replaced by the percentage of the TOE and the only constraint was that the unit's current surviving percentage not exceed 100.

ATLAS now considers that the model computes replacements based on the difference between TOE and current strengths. The total number of replacements per day to a sector is constrained by an input factor which is a percentage of the TOE strength. In addition the user must specify the order of priority in which active, reserve, withdrawn, and un-committed units are to receive replacement. The replacement

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percent of each unit status is redefined to represent the percentage of shortfall (TOE - current strength) to be replaced.

The formulas of the new personnel replacements policy used in ATLAS are in the following form:

$$\begin{Bmatrix} \text{The Number of} \\ \text{Replacements} \\ \text{Desired} \end{Bmatrix} = \left(1 - \frac{\text{Current \%}}{\text{Strength}} \middle/ 100\right) \left(\frac{\text{TOE}}{\text{Strength}}\right)$$

$$\left(\frac{\text{Replacement}}{\text{Percent}} \middle/ 100\right)$$

$$\begin{Bmatrix} \text{The Rate (\%) of} \\ \text{Number of Replace-} \\ \text{ments Allowed} \end{Bmatrix} = \frac{\begin{Bmatrix} \text{The Maximum Number of} \\ \text{Replacements Allowed} \end{Bmatrix}}{\begin{Bmatrix} \text{The Number of Replace-} \\ \text{ments Desired} \end{Bmatrix}}$$

Example:

Unit Status	Replacement Percent	Priority
Active	50	1
Reserve	33	1
Withdrawn	75	1
Uncommitted	0	1

Units in Sector	TOE Strength	Current % Strength	Unit Status
A	100	80	Active
B	100	70	Reserve
C	100	60	Withdrawn
Sector TOE Strength	300		

Maximum % of TOE strength that can be replaced: 10%/day

Maximum number of replacements: 30/day

$$\begin{pmatrix} \text{Desired Number of} \\ \text{Replacements} \end{pmatrix} = \begin{pmatrix} 1 - \dfrac{\text{Current } \%}{\text{Strength}} / 100 \end{pmatrix} \begin{pmatrix} \text{TOE} \\ \text{Strength} \end{pmatrix} \begin{pmatrix} \text{Replacement} \\ \text{Percent } / 100 \end{pmatrix}$$

A	10
B	10
C	30
	──
	50

Therefore, the rate of the allowed number of replacements to the desired number of replacements is: Allowed/Desired = 30/50 = 60%. This demonstrates the effect of the maximum number of replacements constraint.

	Desired Number	Allowed Number	New % Strength
A	10	6	86
B	10	6	76
C	30	18	78
	──	──	
	50	30	

The effect of changing priorities is demonstrated by the following. If the priorities had been set to active = 1, reserve = 2, withdrawn = 3, then

	Desired Number	Allowed Number	New % Strength
A	10	10	90
B	10	10	80
C	30	10	70

If the priorities had been set to active = 1, withdrawn = 2, reserve = 3, then

	Desired Number	Allowed Number	New % Strength
A	10	10	90
B	10	0	70
C	30	20	80

The above example shows the procedure of how to determine the new percent of TOE strength by the recent modificated logic of the personnel replacements within the ground-combat model of ATLAS. This is a prominent improvement in the treatment of personnel replacements including some other parameters of ATLAS. Thus, changes to the model logic and input were made (see [10]). The ability to specify the maximum replacement percentages, replacement priorities, in addition to rates to be used for active, reserve, withdrawn, and uncommitted units, provides a wide range of alternative personnel policies for consideration by the planner. To emphasize again, ATLAS is extremely sensitive to the capability of either side to replace battle casualties. Selection of personnel replacement inputs for ATLAS should be given careful attention.

F. AIR ALLOCATION

1. Allocation of Aircraft to Sectors

Daily operation of the tactical-air model is dependent on an air-control authority (ACA), simulated within the tactical-decision model. ACA assigns combat aircraft to each battle sector on the basis of enemy ICE per sector and the

overall aircraft availability. However, the allocation of
aircraft to each sector by the ACA is not done entirely on
the basis of the ICE of the units involved. Certainly the
ICE permits an initial designation of aircraft, but an
additional step in sector selection is warranted. This step
is to determine the maximum number of aircraft that each
sector can accommodate, based on the capacities of airbase
within range of FEBA and the supplies available at the air-
bases to equip and sustain combat sorties. The number of
aircraft which each sector can accommodate is determined as
follows:

$$N_i = \min \left[\frac{n_j C_j}{s} \quad , \quad \frac{(OH)_j}{s \, t} \right] ; \quad i = 1,\ldots,m$$

where N_i = number of aircraft ith sector can accommodate,

$\quad$ B $\,$ = number of sector airbases within combat range of
$\quad\quad$ FEBA,

$\quad n_j$ = maximum sorties per for jth airbase,

$\quad C_j$ = present airbase capacity (percentage) for jth
$\quad\quad$ airbase,

$\quad (OH)_j$ = on-hand supplies of jth airbase,

$\quad$ m = number of sectors controlled by the ACA under
$\quad\quad$ consideration,

$\quad$ s = sorties per aircraft per day, and

$\quad$ t = tons of supplies consumed per sorties.

2. Allocation of Aircraft to Airbases

After the model has allocated combat aircraft to
various battle sectors, the model assigns the aircraft to
airbases within the sector for a home-base location and
logistics support. The number of aircraft which the partic-
ular airbase will receive is limited by one of the following
three values: (a) the number of aircraft to be assigned to
the sector, (b) the present airbase capacity, or (c) the
supply level at the airbase to equip and sustain sorties.
Thus, the minimum function is expressed as follows:

$$N_j = min \left[A_1 \ , \ \frac{n_j \ C_j}{s} \ , \ \frac{(OH)_j}{s \ t} \right] \ ; \ j = 1,\ldots,B$$

where N_j = number of aircraft the jth airbase will receive,
and

A_i = number of aircraft to be assigned to the sector.

Thus, if $N_1 = A_i$, the most forward airbase (j = 1) receives
all the aircraft assigned to this sector for the day's
actions. If $N_1 < A_i$, then $R = A_i - N_1$ is assigned to next
most forward airbase (j = 2). If there are still A_i aircraft
to be assigned, the airbase (j = 3) is then made active for
this day, and so forth.

3. Allocation of Aircraft to Air-Missions

To have the model operate on a 24-hour cycle from
day to day without additional air mission orders requires
a routine to assign aircraft to tactical air mission each
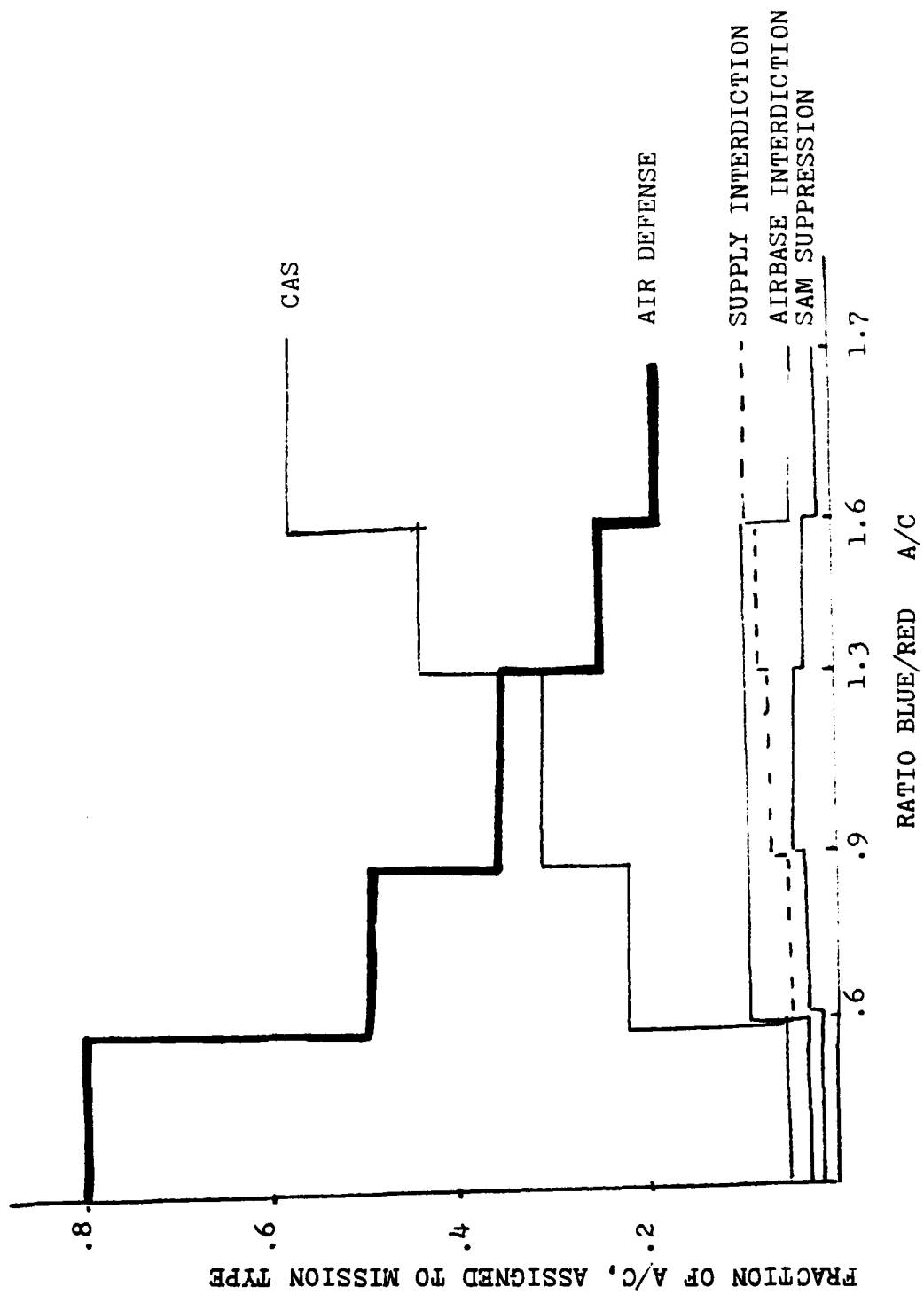day. The model was designed to assign aircraft to the

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Fig. 5-5 Aircraft Mission Assignments

following three type missions: (a) air-superiority missions, (b) CAS[11] and (c) interdiction-type missions. The selection of aircraft per mission assignment curves as shown in Figure 5-5. The number of aircraft assigned to each mission is determined by the relative strength of air power per sector. Figer 5-5 shows that as one side achieves air superiority, more and more aircraft are assigned to CAS and interdiction missions. ATLAS allows that a. set of similar curves are employed in different runs of the simulation.

The tactical-air model of ATLAS requires that a different set of curves be made available to both the Red and Blue forces. It is also possible that different tactical postures warrant other air mission assignments. For example, the Blue defense force, if it has air superiority, may wish to assign a high percentage of the aircraft on CAS missions. However, if the same force is in a stalemate situation, a high

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[11]The CAS effects in the model are determined in a very straightforward manner. Various studies have indicated what a standard or near optimum munition loading would be for aircraft on a CAS mission. Using this standard loading and computing the lethal area of effects for the munitions, an equivalent ICE for a CAS aircraft can be calculated. This value multiplied by the total aircraft assigned to CAS yields the ICE that is to be added to the combat unit's ICE and then assessed in the ground model for that day's action. The ICE for CAS is computed on a daily basis to account for loss of aircraft and/or changes in CAS tactics.

percentage of interdiction missions may be of tactical importance. In this situation the model is flexible enough to accept all variations in mission assignment, providied that they are entered before each computer run.

G. AIR-DEFENSE OPERATIONS

The air-defense operations of the model are designed to assess the effectiveness of the air-defense fighter (interceptor), SAM units, and air-defense artillery (ADA) weapons. Thus, the losses of attacking aircraft by the air-defense operations are assessed. The model assumes that air-to-air battles occur concurrently with each mission assessment. The losses by the air battle between attacking aircraft and interceptors in a given *sector are determined as follows:*

$$\Delta A = \min (P_1 A_3 , a A),$$

Where ΔA = number of attacking aircraft lost to interceptors,

A_3 = number of aircraft allocated to the air-defense role,

P_1 = kill probability of interceptors vs attacking aircraft,

a = attrition constant to attacking aircraft, and

A = number of attacking aircraft.

$$\Delta A_3 = \min (P_5 \min(A, A_3) , b A_3),$$

where ΔA_3 = number of interceptors lost to attacking
aircraft

P_5 = kill probability of attacking aircraft vs
interceptor, and

b = attrition constant to interceptor.

The air-defense routine of the model also determines the
number of aircraft lost to SAM units as each sector is
penetrated by the enemy attacking aircraft. Within each
battle sector there may be more than one concentration of
SAM units in depth from FEBA. Depending on the theater, there
may be more than one type of SAM unit deployed. Since each
SAM concentration is characterized in the model by the number
of fire-units available, SAM effectiveness against attacking
aircraft can be determined within the model as follows:

$$\Delta A = \min (P_2 F , c A),$$

where ΔA = number of attacking aircraft lost to SAM units,

P_2 = single-salvo-kill probability (SSKP)[12] of SAM vs
attacking aircraft,

F = number of fire units at the site, and

c = attrition constant to attacking aircraft as one
SAM site is penetrated.

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[12]In computing the aircraft lost to SAM fire, two SSKP's
are used. All kill probabilities are based on the type of
missile system deployed and its firing doctrine which may be
one, two, or more, missiles per salvo. One value is applied
against aircraft whose mission is to attack the missile site,
and another value is applied to all other missions. Since SAC
aircraft generally operate at a lower altitude, they receive
the lower value missile assessment and thereby become more
vulnerable to air defense artillery weapons in the area.

The air-defense operations also includes to assess the ADA weapon effectiveness. The number of attacking aircraft lost to ADA weapons in each sector is assessed as an overall attrition constant per sector as follows:

$$\triangle A = d\,A,$$

where $\triangle A$ = number of attacking aircraft lost to ADA weapons,
and

d = attrition constant to attacking aircraft.[13]

Air-defense operations all utilize measures designed to destroy or reduce the effectiveness of attack aircraft, including air-defense fighters, SAM units, and ADA organic to ground-combat units. In the equations for the assessment of air-defense operations, as presented above, "kill probability" and "attrition constant" are intended to be the governing factors determining air-to-air losses. However, input parameters such as those two cannot be accurately computed or derived from historical experience. With the extensive use of ATLAS during past years the tactical-air model input parameters have been studied and refined so that the overall mission loss rate corresponds fairly well to recent experience. This does not mean, however, that each

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[13] The attrition constant d is a weighted average of the effectiveness of ADA weapons to combat divisions and supporting elements within the sector. Hence as aircraft penetrate a given sector, the attrition constant for that sector is assessed against the aircraft. Once the attrition constant is determined for a combat division, the ratio of ADA effectiveness to division ICE will remain constant. Then as the division ICE is reduced by battle effects, the corresponding ADA attrition constant is similarly reduced.

input parameter necessarily valid or in perfect balance with the others. Specific values for determining an attrition constant may be found in the THEATERSPIEL Manual.[14]

H. COUNTER-AIR-DEFENSE OPERATIONS

Counter-air-defense operations (CAO) are designed to encompass airbase-interdiction and SAM-suppression missions. The detailed effects assessed are air strikes against SAM fire units and the loss of enemy air capability by means of interdiction of airbases and supporting air facilities.

Within each battle sector the model recognizes that SAM capability may be deployed at various depths from FEBA. Once the number of aircraft attacking a given SAM sites is known, the SAM losses may be computed. Since the SAM-suppression aircraft are assigned to SAM sites in ratio to the strength of fire units at each site, and aircraft attacking rearware SAM units come under fire from forward SAM units but with a lowered value of kill, the form of the loss assessment may then be given as:

$$\Delta F = \min (P_3 A_1, e F),$$

where ΔF = number of SAM fire units destroyed,

   P_3 = probability of one attack aircraft destroying on fire unit,

   A_1 = number of aircraft attacking this SAM unit,

   e = attrition constant to fire unit from attack aircraft, and

   F = number of fire units at this SAM site.

The number of aircraft assigned to attack each SAM site is in proportion to the number of fire units at the site. The number of fire units lost to aircraft attack is a function

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[14] Research Analysis Corporation, "THEATERSPIEL Manual," Vol IV, "Tactical Air Model," unpublished manuscript, Aug 66.

of the number of fire units available at the site, the
effectiveness of the aircraft attacking the SAM units, and
the total number of aircraft attacking the site.

Active airbases within range of the opposing airforces
are also vulnerable to interdiction. The interdiction
assessment is made against the airbase capacity, on-hand
supplies, and parked aircraft. The losses are determined by
the following formulas respectively:

Air-Base capacity

$$\Delta C = C \left[1 - \exp \frac{-k_1 g A_5}{C} \right]$$

where ΔC = percentage of degradation of airbase capacity by
interdiction

C = present airbase capacity as percentage of maximum

A_5 = number of aircraft that attack a given airbase

g = percentage of A_5 aircraft that attack airbase
facilities

k_1 = attrition constant to airbase capacity[15]

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[15]The attrition constant to airbase capacity is based on
data from the Defense Intelligence Agency (DIA) Physical
Vulnerability Handbook and listed as tabular data in an AWC
"Analysis Seminar Control Manual," published by Army War
College, Feb 66.

On-hand supplies

$$\triangle OH = (\triangle C / C) \, OH$$

where $\triangle OH$ = tons of on-hand supplies lost by interdiction

OH = tons of on-hand supplies of a given airbase

Parked-aircraft

$$\triangle A_a = \min \left[P_4 \, h \, A_5 \, , \, (1 - ORF) \, A_a \right],$$

where $\triangle A_a$ = losses of parked aircraft at a given airbase by interdiction,

P_4 = probability of killing a parked aircraft on one bombing pass, and

ORF = overall-reliability factor.[16]

A_5 = number of aircraft attacking this airbase

h = percentage of A_5 aircraft that attack parked aircraft

A_a = number of aircraft allocated to this airbase

When attacking enemy airbases the number of aircraft assigned to attack each airbase is a function of the nearness of the airbase to the FEBA and the ability of the airbase to handle large numbers of aircraft sorties per day. Thus, whenever an airbase is attacked, the capability of the airbase to sustain a given number of sorties per day is a characteristic that is degraded. The attrition constant (k_1 in the above formula) to

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[16] ORF may be considered as representing the expected number of effective sorties per day per aircraft assigned. The ORF value is an input to the model and based on assumed values of the individual events.

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be applied to airbase capacity (loss in sortie capacity) as a result of each airbase interdiction is quite difficult to estimate because (a) sortie capacity lost at airbases is recovered on a daily basis, and (b) in the games played to date airbase capacity has not been a particularly limiting factor. In order to better identify the overall effect of air parameters ATLAS allows players to conduct "sensitivity analysis." Although this technique may sometimes distort loss rates it is believed that it does permit a better evaluation of the impact of each of the parameters.

I. AIR INTERDICTION

The tactical-air model is also designed to assess air interdiction of supply points. This type interdiction is generally most critically felt in the forward battle areas. Resupply into these forward areas is of the greatest importance since losses tend to create a loss of combat effectiveness within a day or two. The interdiction assessment has aircraft attacking supply nodes in depth from FEBA out to the combat range of the aircraft. The aircraft are assigned to each node in proportion to the size of the node as determined by its air-resupply capability. Thus, the damage at each node is assessed as (a) loss in tons to LOC capacity, (b) tons of supplies destroyed, and (c) tons of air-resupply capability lost.

The LOC capacity of each supply node is a function of the capacity of the rail and road network of the lines of supply and the logistics effort required to keep the unit at maximum

effectiveness. The present output capacity is assumed to
drop if either the supply lines are interdicted or the
logistics unit suffers a reduction in strength. With the
present output capacity taken as an index to the vulnerability
of the LOC, an "exponential decay" assessment is assumed
acceptable to express damage to LOCs and reduction of logistic
support. Thus, the reduction in output capacity of a given
model is given as follows:

$$\Delta OC = OC \left[1 - \exp \frac{-k_2 t A_2}{OC} \right] \quad ,$$

where ΔOC = reduction in output capacity of this node, tons,

OC = present output capacity of this node, tons,

k_2 = attrition constant to output capacity,

A_2 = number of interdiction aircraft attacking this
node, and

t = percentage of A_2 aircraft attacking output
capacity.

Two other characteristics of supply nodes are recognized
as vulnerable to air interdiction. These are the air-resupply
capability available to some supply nodes and the on-hand
supplies at the node. The interdiction to air-resupply
capability is in actual fact the loss of parked transport
aircraft at the supply node, as well as a loss in airfield
capability to handle the transports. The degradation of the
air-resupply is similar to the "exponential decay" assessment

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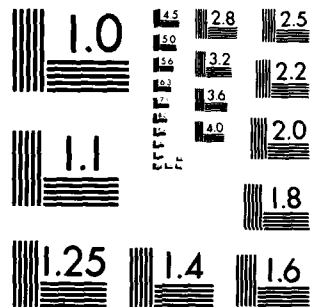   MAR 80   M K NAM

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MICROCOPY RESOLUTION TEST CHART
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used previously but with a different attrition constant. The
loss of air-resupply capability ($\triangle$ AC) is:

$$\triangle AC = AC \left[1 - \exp\left(\frac{-k_4 r \, A_2}{AC} \right) \right] ,$$

where AC = total air-resupply capability of present nodes,
          tons,

      k_4 = attrition constant interdicting this node, and

      r = percentage of A_2 aircraft interdicting air-resupply

The loss of on-hand supplies from an interdiction mission
is also assessed by the "exponential decay" expression.
Using the attrition constant for on-hand supplies, the loss
of on-hand supplies at a given node (OH) is:

$$\triangle OH = OH \left[1 - \exp\left(\frac{-k_3 s \, A_2}{OH} \right) \right] ,$$

where OH = supplies on-hand at this node, tons,

      k_3 = attrition constant for on-hand supplies, and

      s = percentage of A_2 aircraft attacking on-hand
          supplies.

As presented in above formulas, the three factors used to
assess losses are (a) attrition to node output capacity,
(b) attrition to on-hand supply, and (c) attrition to aerial
resupply capability. The sensitivity test of these factors
(see p.95 [1]) shows the Red losses per Blue sortie as Blue
interdiction factors are increase - substantially linearly.
When LOCs are tenuous or the level of supplies critical the

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value assigned to these three attrition factors can be important. The overall effect on combat operations of LOC and air-resupply attrition, however, is directly related to the daily recovery rate of node output capacity and air-resupply capability. Both attrition and recovery factors are "judgemental" and often can be evaluated only in the context of overall game results.

J. LOGISTICS - CONSUMPTION AND AVAILABILITY

Three external demands for supplies are given at a node: (a) demand from the ground-combat units, (b) demand from SAM sites, and (c) demand from tactical-airbases. When total demand on a node exceed supplies available at the node, supplies are delivered in proportion to the demand.

The demand for resupply of a ground combat unit is specified as the number of planned days of supply that a unit should carry with it into battle. The planned day of supply is the amount of supplies a unit is considered to consume per day over an extended period of time. The sum of the planned day of supply in a sector is calculated so that stockpile requirements should be also met at each node. The consumption of a ground-combat unit supplies is a function of the unit type, its status, strength, and posture.

Each SAM site and tactical-airbase is associated with a particular node that is responsible for providing them with supplies. SAM sites are assessed to demand supplies at a constant rate per battery, based on an assumed level of

activity. The demand for resupply at a tactical-airbase is
the difference between actual on-hand supply levels and the
authorized stockpile. The consumption of tactical-airbase
supplies is a function of the number of sorties flown from
the base.

As discussed in section B of Chapter III, in keeping
with the philosophy that all supplies and new units should,
if possible, be moved over the ground LOCs, remaining ground
output capacities are used to send new units to a more for-
ward node and then to send supplies to meet stockpile
requirements of the forward node. All the supplies leaving
a node by ground means do not necessarily reach the next node.
Loss in ground output capacity due to enemy interdiction may
occur when supply convoys are actually on the road. Quant-
ities of supplies lost in this manner are difficult to
determine, but in the model it is assumed they are proportional
to the fractional loss in capacity. Hence, the supplies
reaching the next node ($\overline{\overline{FS}}$) are given by:

$$\overline{\overline{FS}} = FS \left(1 - \frac{\Delta OC}{OC}\right) ,$$

where FS = supplies sent forward from a node,

   OC = nominal ground output capacity of the node, and

ΔOC = loss of ground output capacity.

Supplies sent forward by air are not subject to losses since
the tactical-air model does not consider the interdiction of
transport aircraft in flight. Although the logistics model
is reducing output capacities owing to interdiction, the

recovery from previous losses must also be considered. In the absence of better data it is assumed that a loss in ground output capacity can be recovered completely with two day's delay.

VI. DISCUSSION OF OVERALL CHARACTERISTICS OF ATLAS

A. GENERAL

As pointed out in the Introduction, the primary purpose of this thesis is to examine the conceptual bases of the ATLAS model and hence to provide potential users with a better understanding of the model. Consequently, the logic and assumptions of each submodel within the overall combat simulation and the significant functional areas of the model have been examined. However, for the intellectual use of the model it is felt that the more comprehensive descriptions require the detailed explanation of the of the strength, weakness, and other important characteristics of the model.

One limitation of ATLAS is the highly aggregated nature of the model. Another problem is that such models are frequently used like "black boxes." Without deep knowledge of the model, the use of the model would result in erroneous conclusions. Current documentation of ATLAS sparsely points out those implications and characteristics of the model. Hence, this Chapter deals with the overall characteristics of ATLAS-- limitations, strengths, applications, improvements, computer-related aspects, and documentation.

B. MODEL LIMITATIONS

There are many factors of actual combat of which the ATLAS model does not take into account, such as the effects

of weather, intelligence, training, morale, combined arms, C^3 (command, control, and communication), or the tactical skill of particular commanders. In fact, it is recognized that in real combat such pervasive factors often play a dominant role. However, in force planning it is unwise to attribute these tenuous factors to one side or the other side. The actual conditions of possible combat are unknowable at the lead time at which the force planner works. Therefore, the planner must emphasize in his analysis those combat factors that he can control or that are calculable.

As described in previous Chapter, in ATLAS the rate of advance is determined on the basis of assumed relationships between force ratios and rate of advance which are furnished as inputs. The validity of the results of these analyses are limited to very few days of intensive engagement because of a number of considerations including the following: (a) Inflexibility of the rates of advance estimated as a function of force ratio, (b) Uncertainty of casualty rate estimates as function of force ratios, (c) Inadequate representation of logistics or aerial interdiction, (d) Inability to simulate the strategic and tactical decisions of a theater commander, and (e) Limitation of the simulation to fixed, parallel sectors excluding consideration of flanking movement, penetrations, etc.

In general, limitations are taken to mean as those representations of combat which appear to be poor approximations to reality. Many of these limitations are not

immediately apparent from a description of the logic; they only surface through unrealistic combat outcomes. Some limitations resulting from the view of combat taken by ATLAS are listed as follows:

1. The use of aggregated linear firepower scores for manpower, combat support and even CAS units completely precludes the use of ATLAS for force mixes analysis. Furthermore, firepower scores only represent the relative estimated capabilities of nominal battalion types, and these scores only express implicitly the effect of unit organization, equipment parameters, mobility characteristics, etc. Also, firepower scores are based on expected expenditures of ammunition that have relatively little demonstrable connection with target opportunity, tactical situation, or the particular force mix being analyzed.

2. The battle sectors in ATLAS are assumed to be independent. Thus, each sector combat force is allowed to disregard its flanks and never finds a position untenable because of enemy success in an adjacent sector. In some situations, this limitation may be a serious deficiency. Actually, U.S. or Soviet doctrine for conducting offensive operations in a conventional war considers the special FEBA configurations such as penetrations, sieges, or intermingling of forces. A detailed discussion concerning this point may be found in Banis [15].

3. The logistics model in ATLAS is such that units in one sector can be denied supplies, and hence the units lose

all their combat effectiveness, while units in adjacent sectors feel no effects of shortages. Furthermore, a unit will continue to fight at full intensity, despite a degradation of LOC capabilities. Because of this limitation, many ATLAS users choose to bypass the logistics model by using artificially inflated LOC capabilities and incoming supply rates.

4. ATLAS results are very sensitive to assumptions regarding the degradation of unit effectiveness as a function of casualties incurred, and the proper number of replacements instantly bring the unit up to full combat capability. This also affects analyses of protracted combat severely.

5. The allocation of tactical air sorties can lead to unrealistic results where Red aircraft are assigned to one sector and Blue aircraft to another. Furthermore, assignment of air missions as a function of tactical air force ratio is said to be an inaccurate representation of actual tactical air employment strategies.

6. Decision processes are very crudely simulated, and there is no provision for planning a strategy.

7. ATLAS does not include all of the forces that would determine the viability of an initial or sustained defense; in particular neither attack helicopters nor airborne troops are included.

8. The combat service support model does not represent the varying requirements of different type combat units.

The only distinctions made are their quantitative effectiveness and gross movement rates.

C. MODEL STRENGTHS

In general, ATLAS is somewhat lacking in realism in terms of the decision maker's needs by its characteristics of deterministic model, but has good responsiveness and a fairly low resolution. Thus, ATLAS has gained wide use by military planners because of, particularly, their speed of operation and relative simplicity. Some strengths of ATLAS are briefly listed as follows:

1. The principal advantage of ATLAS is the rapid speed with which large-scale combat can be simulated. Once the theater forces and environment have been analyzed and the input data prepared, any of the planning assumptions and alternatives can be examined within minutes of computer time.

2. The analyst can readily change inputs during and between computer runs. For example, at the end of each runs, final values of evolving state variables are written onto a magnetic tape. Should it then be necessary or desirable to continue that run this tape may be used as input and the previous run is resumed where it left off. There is no need to begin anew.

3. The output of the ATLAS program has been designed to give the user options for time and space. These options are the time interval desired of the printout, the frequency of the printout, and the method of printout in a sense combining the first two options.

4. ATLAS can be used to gain "insights." From a theater viewpoint ATLAS encompasses most of the parameters of combat operations at about the level of detail as would be available in theater contingency planning. However, it need not try to resolve combat operations to a fineness not warranted by the game structure. If specifics on tactics, weapons, or organization are required it will be necessary to use a more deliverate lower resolution war game.

5. Real data of ATLAS exists to simulate Korea, Mid East, AFCENT, and NEA. Since all models depend on data, sources of data are a primary concern of the analyst.

D. MODEL APPLICATIONS

ATLAS has been used extensively both within the Army and at other agencies. According to a record[17] in 1977, the approximately frequency of use of ATLAS was 600 times per year which is the highest frequency of use of current theater-level combat models. SHAPE Technical Center conducted the ACE capability study with ATLAS. The JCS Studies Analysis and Gaming Agency has evaluated contingency plans for Korean and the Mideast using ATLAS. The most recent Army applications have been with the FOREWON System in support of the Army Strategies Objective Plan.

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[17] Studies, Analysis, and Gaming Agency, Organization of the Joint Chiefs of Staff, "Catalog of War Gaming and Military Simulation Models (7th Edition), SAGA-180-77, Washington, D.C., August 1977.

Some of the problems facing today's military planners are the <u>how</u>, <u>when</u>, and <u>where</u> problems of contingency planning: (a) How are troops, supplies, and equipment best transported to a conflict area under certain political or least-cost constraints? (b) Which force-closure schedule gives maximum effectiveness to the strategy employed? and (c) Where should the force be applied in the face of alternative contingencies? Although there appears to be general agreement on the military and deterent value of rapid force deployment, determination of the appropriate force level is another matter. For each contingency area the questions of force size and deployment speed are problematical. Many contingencies represent varied and uncertain threats, and hence no unique requirement becomes apparent. However, the status quo could still be reestablished in a conflict area that had been overrun and later retaken.

The primary application that is advantageous in contingency planning is to be able to be played in either a requirements or a capabilities mode. By successive iterations, ATLAS can estimate either the theater force required and the times that reinforcing units must arrive in theater to hold an enemy at a given defensive line or the force required to seize an objective. In the capabilities mode, ATLAS can be used to estimate when and where a given force deployed over an indefinite period will stabilize the enemy's advance. Another major application of ATLAS is to test the assumed enemy attack to determine whether it is in fact the strongest

threat that the enemy force can marshal given the initial scenario conditions. To maximize the enemy threat in this way creates more confidence in the final estimate of friendly capabilities.

However, ATLAS has severe limitations, as described in previous Section, even for this relatively narrow application. In other words, those limitations restrict the various application of ATLAS. Some restrictions of ATLAS' application are listed as follows:

1. Nonlinear FEBA; ATLAS is not applicable in nonlinear FEBA situations. No envelopments, penetrations, or flanking maneuvers are sllowed.

2. Maneuver and Fire Support; Analysis of the mix of maneuver and fire support units in ATLAS is precluded because of the linearity of firepower score. The combined arms effects associated with different types of units cannot be portrayed, and thus the outcomes of theater battle are not sensitive to changes in mix.

3. Ground/Air Trade-offs; ATLAS considers CAS as equivalent to artillery. Thus, ATLAS is not useful for ground/air trade-offs.

4. Combat/Combat Service Support Trade-offs; ATLAS is inadequate for evaluating combat/combat service support trade-offs. Although ATLAS explicitly represents the flow of supplies through LOC's in a logistics submodel, the relationship between supply constraints and combat effectiveness is quite unrealistic.

5. Force Employment; ATLAS is virtually precluded from studying variations in force employment. No grand maneuvers or innovative tactics can be represented.

E. MODEL IMPROVEMENTS

The ATLAS model has been most extensively used in studies performed at CAA (Concepts Analysis Agency). In August 1973 the Review Methodology Working Group of the OSD/Army NATO Land Force Requirements Review Steering Committee identified areas of the model which required improvements. The improvements in the treatment of barriers and personnel replacements have been made and tests to compare results of the modified version of ATLAS with the pre-modification model have been completed. (See [10])

However, those modifications of ATLAS were undertaken in order to improve the use of just a few of input parameters. Some of the present assessment procedures are still recognized as inadequate. Furthermore, it is anticipated that all the models in ATLAS will undergo some modifications in order to improve the credibility and validity of the game. It is believed that sufficient understanding of combat operations at the ATLAS level of aggregation is now available within the state-of-the-art of gaming to correct most of the known inadequaties. Some sacrifice in speed of play will probably have to be accepted as the price of continued improvements.

Relating to the research required for the model
improvements, <u>Models</u> <u>Review</u> <u>Committee</u> (see [7]) said that
the most important aspect of an improved capability to
simulate theater-level combat is not in the increased
sophistication of the model itself but in improved inputs
and engagement assessment routines. The Committee went on
to say that the model should therefore be designed or mod-
ified for maximum "visibility" of the interactions of inputs
and assumptions and their impact on game results so as to
permit the ready application of judgement. Some of the
possible improvements or research areas of ATLAS are
identified as follows:

1. Development of a methodology for generating force
ratios which are sensitive to organizational, tactical weapon
system considerations will improve the results of the analysis
and could permit limited force structure analysis.

2. Development of improved firepower scores could make
them more sensitive to weapon system effectiveness, force
mixes, and organizational aspects. There are currently a
number of efforts underway to improve firepower scores. One
of these efforts is sponsored by SAGA, STAG, and European
agencies.

3. FEBA movement rates and units rates of advance were
originally developed on the basis of limited historical data.
The rates have been subsequently modified, changed, and
aggregated so that current rates of advance have little
traceable connection with historical fact. How best to use

the available military judgement or other scientific validation estimates of the rates are required for the improvement of ATLAS utility.

4. Casualty data as a function of force ratios and tactical postures is based on analysis of WWII engagements. The translations of casualty rates to material loss rates and vice versa is likely to be different in future wars as compared to past wars, particularly with respect to highly mechanized campaigns.

5. The effect of personnel and material losses on unit effectiveness needs to be studied further in the context of different engagements and missions possibly by the use of lower level games.

6. More effective methodology for introducing the effect of logistic constraints on the model needs to be investigated.

7. In using the better historical data or a limited capability to extrapolate historical data to future wars, it is essential that division level models and higher resolution models be designed to provide better estimates of critical inputs to the model.

8. Improvement of the air model and a more realistic analysis of logistics would substantially improve the usefulness of ATLAS.

F. COMPUTER-RELATED ASPECTS

There now exists ATLAS programmed in FORTRAN IV capable of being run on the IBM-360/50 or 360/65, CDC-3600 or 6000,

and UNIVAC-1108 computers. Other requirements of the hardware are (a) the minimum computer storage requires 186K bytes of core for IBM machines; 120K for CDC, (b) the peripheral equipment requires up to two 9-track tape drives and/or a 2316 disk pack for IBM machines; up to two drives for CDC 6000 series. The operating time of the simulation averages 10 seconds of computer time for each day of computer, or 6 days of computer per minute of computer time. This time includes data read-in time, assessment time, and data print-out time.

Requirement of ATLAS for input data is quite large; approximately 10,000 input data. The amount of time for preparation of those input data and other time requirements for a game with ATLAS are a significant problem for the player. The overall time requirements for the game of ATLAS which has roughly estimated by SAGA [17] are:

- 2-4 months to acquire base data, depending on service responses,

- 1 man-month to structure data in model input format,

- CPU time per model cycle: CDC 6000 Series: .2 minute
  IBM 360 Series: .6 minute,

- 1-2 months learning time for players, and

- 2 to 40 man-hours per run to analyze and evaluate results.

To some extent, severity of those time requirements is mitigated by preplay operations, as a guide prior to the use

of more detailed computational aids. An experienced analyst

will generally require from 2 to 3 man-weeks, depending on

the availability of the data, to assemble the data for the

preplay.

The initial computer program of ATLAS was for IBM-7044

computer and the program has later converted to CDC-6400

computer. Recently ATLAS has been reprogrammed for the IBM-

360/50 or 360/65 and the CDC-3600 computers. However, when

one desires to use the program for its own computer system

one might face difficulty in the "program conversion."

Actually, this sort of problem has been indicated by

most of the new users of the ATLAS model and was particularly

criticized by Szymczak [16]. In his report, he explicitly

tells us the significance of problem on "program conversion"

or "model transfer" as follows:

> ...the concept was to acquire the ATLAS model, convert it
> for use on IBM-360/50 computer, develop a manual, and run
> the model to analyze...

> ...in late Feb. 1979, the ATLAS model arrived via a magnetic
> tape and the above plan proceeded to be executed. After 4
> man-months and 190 minutes of CPU time, the model had been
> debugged and linked and was ready for development of
> setup and run procedures. This was greatly in excess of
> the expected time to complete the task, given that the
> model has been inexistence for ten or more years and is
> considered "simple" compared to other theater-level
> models. Why had its transfer required the expenditure of
> effort indicated above?...

In addition to the problem of excessive transfer-time, the

direct computer costs could be another problem (remember

that CPU time per ATLAS model cycle is .6 minute for IBM

360 series). Relating to the above problems, what we per-

ceive is that even though the model has existed and has been

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used for many years its transfer is hampered by limited documentation. Based on these insights, the thorough investigation of how documentation limits the easy transfer of existing models between agencies and other critical examinations of model-transfer are given in detail by Szymczak [16].

G. DOCUMENTATION

In this section, we shall consider the following question: What about the status and adequacy of the current documentation of the ATLAS model? Actually, the adequacy of model documentation is the primary concern to the user of the model since deep understanding of the model could be given through the adequate documentation.

Model documentation is generally defined to be a collection of information to explain the design, development, and maintenance of the model as well as purposes, methods, logic, relationships, capabilities and limitations. Documentation is necessary for: planning, programming, managing, operating, and evaluating the model. Thus, the adequate documentation should meet some essential requirements: quick and effective transfer of the model, easy use of the model by analysts other than the originators, conceptual description of what is being done within the model, verification of proper model operation, etc.

ATLAS is currently documented in two TAC technical publications: (a) RAC-TP-266 Nov. 67, "Computerized Quick Game: A Theater-Level Combat Simulation," and User's Guide."

CAA Technical Paper CAA-TP-73-3, "Modifications to ATLAS,"
July 1974 describes the modifications made to the ATLAS
model logic and input procedures. Those two volumes are
restricted to only a general description of the model. A
more comprehensive description of the structure, logic,
functional areas and other conceptual aspects of the model
is not included. On the adequacy of the model, Szymczak
[16]said:

> ...at the highly aggregated level the guidance for the
> model user is necessarily general, as it moves down the
> organization further more explicit implementing directives
> are provided culminating in directives issued by the
> developing agency. Hence, some documentation is brief
> and simplistic; other documentation is detailed and
> voluminous and complex. Neither may prove to be ade-
> quate. Adequacy is determined by the ability of other
> than the originators to use and understand the model...

However, as described in Introduction, from the user's
standpoint current documentation of the ATLAS model has been
and still is recognized to be poor, non-persuasive, and
somewhat inadequate.

Then, what is the required level of documentation? At
this point, we feel "the hierarchy of documentation" proposed
by Szymczak is shown to be quite acceptable. He suggests
three levels of documentations for models be required:
(a) Analyst's conceptual documentation, (b) Programmer's
technical documentation, and (c) Decision maker's non-
technical documentation. Particularly, the analyst's
conceptual documentation is the one that determines the
overall worth of the model as analytical tool.

The main purpose of this paper was to examine a conceptual basis of the ATLAS model. Then, what are the basic requirements for the contents of analyst's conceptual documentation? Some are listed below:

1. Information on the input requirements, data base used in the model must be detailed.

2. All constraints and limitations must be described in detail as well as assumptions used, logic, and interactions.

3. Sufficient detail to allow the analyst to mutually trace inputs through the algorithms is neceesary.

4. Mathematical, statistical, and numerical methods incorporated in the model should be described including any new or unique applications.

5. Any constraints which will affect the accuracy of the model must be identified.

6. Obvious pitfalls must be stated; they are only obvious to the developer and in complex models without documentation they can even be forgotten by the developer.

7. The physical processes simulated must be described, including explanation and rationalization of the techniques used.

8. Each variable and the entity it represents must be clearly stated.

9. Sufficient instructions describing how to set up and use the model, and flow charts keyed to the program instructions should be provided.

10. A system that keys the description of each
mathematical formulation in the manual is needed.

VII. <u>CONCLUSIONS AND RECOMMENDATIONS</u>

The purpose of this thesis has been to attempt to offer some observations which might help to enhance the general user's sound understanding of the ATLAS model. It was intended not as a modification or supplementation of the model but as an examination of the conceptual basis of the model itself. Thus a detailed discussion of the conceptual aspects for the logic, functional areas, assumptions and implications, and some important characteristics of the ATLAS model have been presented.

As pointed out previously, we need to note some facts with the ATLAS model: (a) the increased needs of evaluation of recent worldwide operational contingencies and the relative adequacy of ATLAS as a suitable theater-level combat simulation to meet such needs, (b) a significant increase in the frequency of the use of ATLAS: 50 times per year as of 1975; 600 times per year as of 1977, (c) problems of aggregation as a "firepower score" model, (d) problems of validation of FEBA movement and casualties--the major outputs of ATLAS, (e) the inadequacy of current documentation as a general user's guide of ATLAS.

ATLAS has severe implications and limitations even for relatively narrow applications, due particularly to (c) and (d) above. A basic problem with firepower scores is that they are not unique. Rather obviously, the value of the

force ratio will depend on the particular set of firepower scores used. Thus presumably, the rate of advance curves used in ATLAS should also be geared to the particular firepower scores employed. Unfortunately, this is not generally so, and the unsuspecting user should be careful. In actuality varying amounts of "subjectivity" are involved in the development of such a firepower score. For this reason, the firepower-score approach has received a fair amount of criticism. Nevertheless, it is essentially the prevailing approach that has been used to model large-scale combat in currently operational ground-combat models. Note that models used for NATO planning also employ the firepower-score approach and (a) and (b) above.

Further research is needed for the validation of the assumptions used in ATLAS. Overall possible improvements or research areas of ATLAS are given in section E of Chapter VI. Some points where the user should be careful in the use of ATLAS are suggested as follows:

1. ATLAS is probably valid only for periods lasting no more than about a week, without human evaluation. It is felt that cumulative errors resulting from poor casualty and FEBA movement data would most likely make the results very unreliable. In addition, relatively crude modeling of allocation and commitment decisions and the lack of consideration of large scale maneuvers contribute to the problem. It is possible to mitigate some of these problems with more careful use than has been apparent in application of ATLAS, and with better data.

2.   It is further necessary that ATLAS be employed, in conjunction with historical analyses, to generate distributions of types of engagements in different strategic situations and to gain a better understanding of the force employment process.   Such information is necessary to validate and improve simulations, which then can be used for production analyses of many alternatives.

3.   In spite of the appealing simplicity of the model, continued use of ATLAS is somewhat questionable since the various combat processes are not considered explicitly in ATLAS but must be reflected in the aggregated measures employed.   It is difficult, if not impossible, to make adjustments to compensate for the obsolescence of the data used.   The use must take more care not to use the model like "black box" but to assure himself that the model is valid for the particular application, and that he understands completely the implications of his inputs and assumptions.

BIBLIOGRAPHY

1. James G. Taylor,"Force-on-Force Attrition Modelling,"
   Military Applications Section of the Operations Research
   Society of America, Arlington, Virginia, 1980.

2. Robert H. Cole and Edward P. Kerlin, "Computerized Quick
   Game: A Theater-Level Combat Simulation," Vol I, "Models,"
   Research Analysis Corporation, Nov 1967.

3. General Research Corporation, "A Hierarchy of Combat
   Analysis Models," Jan. 1973.

4. James G. Taylor, "Attrition Modeling," in "Operational
   Research Games for Defense," R.K. Huber, et al, R.
   Oldenbough Verlag, Munchen, 1979.

5. J.A. Stockfisch, "Models, Data, and War: A Critique of
   the Study of Conventional Forces," Report R-1526-PR,
   RAND Corporation, Mar. 1975.

6. Bonder, Seth, "An Overview of Land Combat Modeling in
   the US," Preceedings 13th U.S. Army Operations Research
   Symposium, Vol I, p. 73 to 88, Nov. 1974.

7. J. Honig, et al, "Review of Selected Army Models,"
   Headquarters, Department of the Army, Model Review
   Committee, May 1971.

8. Conference on Modeling Land Battle Systems for Military
   Planning, 1974, "Military Strategy and Tactics:
   Computer Modeling of Land War Problems (Proceedings),"
   edited by Reiner K. Huber, et al, Plenum Press, 1975.

9. Research Analysis Corporation, Report RAC-R-36,
   "Theater Battle Model (TBM-68)," Vol VII "Technical
   Report," Jan. 1968.

10. US Army Concepts Analysis Agency, Technical Paper
    CAA-TP-74-3, "Modifications to ATLAS (ATLAS-M),"
    July 1974.

11. Karr, A.F. "On the CONAF Evaluation Model, P-1210.
    Arlington, VA.: Institute for Defense Analysis, 1976.

12. Kerlin, et al. "IDA Ground-Air Model I (IDAGAM I),
    Volume 1: Comprehensive Description. R-199, Institute
    for Defense Analysis, Arlington, VA, Oct. 1974.

13. Emerson, D.E., "The new TAGS Theater Air-Ground Warfare Model: A Description and Operating Instructions," The RAND Corporation, R-1576-PR, Sept. 1974.

14. S.L. Shupack. "An Examination of the Conceptual Basis of the Attrition Processes in the Institute for Defense Analysis Ground-Air Model (IDAGAM)," Naval Postgraduate School, Mar. 1979.

15. F.G. Banis II, "Modeling of the Non-integral FEBA," Naval Postgraduate School, June 1977.

16. R.W. Szymczak, "Transferability a Function of Documentation," Naval Postgraduate School, September 1979.

17. Studies, Analysis, and Gaming Agency, Organizations of the Joint Chiefs of Staff, "Catalog of War Gaming and Military Simulation Models (7th Edition)," SAGA-180-77, Washington, D.C, August 1977.

18. _____, "Catalog of War Gaming and Military Simulation Models (6th Edition)," SAGA-236-75, Washington, D.C., June 1975.

19. Rex Goad, "The Modeling of Movement in Tactical Games," in "Operational Research Games for Defense," R.K. Huber, et al, R. Oldenbourg Verlag, Munchen, 1978.

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